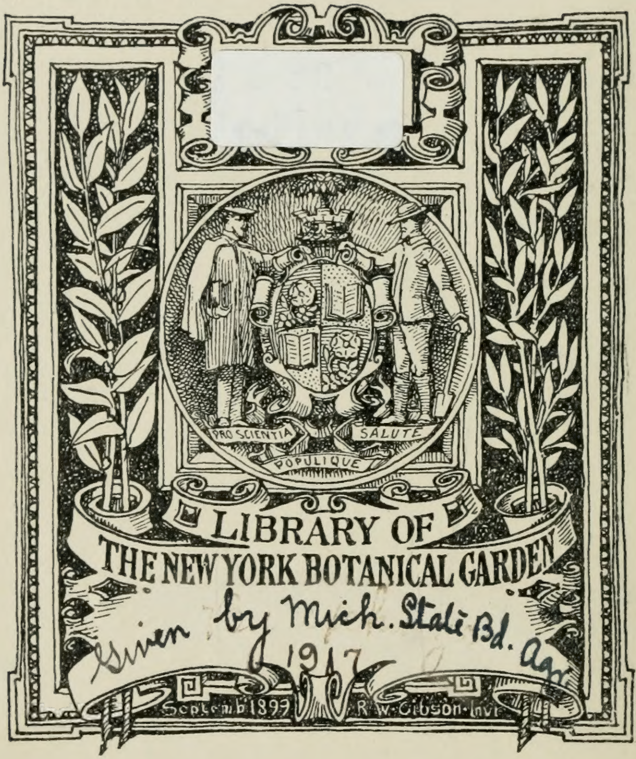

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FIFTY-FIFTH ANNUAL REPORT

OF THE

SECRETARY

OF THE

STATE BOARD OF AGRICULTURE

OF THE

STATE OF MICHIGAN

AND

TWENTY-NINTH ANNUAL REPORT

OF THE

EXPERIMENT STATION

FROM

JULY 1, 1915, TO JUNE 30, 1916

A. D. MDCCCXXXV

BY AUTHORITY

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1916

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REPORT OF THE SECRETARY

OF THE

STATE BOARD OF AGRICULTURE

EAST LANSING, MICH., *July 1, 1916.*

TO HON. WOODBRIDGE N. FERRIS,

Governor of the State of Michigan:

SIR—I have the honor to submit to you herewith, as required by law, the accompanying report for the fiscal year ending June 30, 1916, with supplementary papers.

Very respectfully,
ADDISON M. BROWN,
Secretary of the State Board of Agriculture.

STATE BOARD OF AGRICULTURE

	Term expires.
JOHN W. BEAUMONT, Detroit	1st Monday January, 1918
JASON WOODMAN, Paw Paw	1st Monday January, 1918
ROBERT D. GRAHAM, Grand Rapids CHAIRMAN OF THE BOARD.	1st Monday January, 1920
ALFRED J. DOHERTY, Clare	1st Monday January, 1920
WILLIAM H. WALLACE, Saginaw	1st Monday January, 1922
I. ROY WATERBURY, Detroit	1st Monday January, 1922
FRED L. KEELER, SUPT. OF PUBLIC INSTRUCTION	*Ex-Officio*
FRANK S. KEDZIE, PRESIDENT OF THE COLLEGE	*Ex-Officio*

ADDISON M. BROWN, East Lansing, Secretary.
BENJAMIN F. DAVIS, Lansing, Treasurer.

STANDING COMMITTEES.

DIVISIONS OF AGRICULTURE AND OF VETERINARY SCIENCE	I. R. Waterbury, R. D. Graham.
DIVISION OF ENGINEERING	A. J. Doherty, J. W. Beaumont.
DIVISION OF HOME ECONOMICS	Jason Woodman, I. R. Waterbury.
DIVISION OF SCIENCE AND LETTERS	J. W. Beaumont, W. H. Wallace.
EXPERIMENT STATION	W. H. Wallace, A. J. Doherty.
EMPLOYEES	R. D. Graham, J. W. Beaumont.
FINANCE	R. D. Graham, W. H. Wallace.
COLLEGE EXTENSION DIVISION	A. J. Doherty, Jason Woodman.
BUILDINGS AND COLLEGE PROPERTY	I. R. Waterbury, Jason Woodman.

FEB 3 - 1917

MICHIGAN AGRICULTURAL COLLEGE

(Under control of the State Board of Agriculture.)

FACULTY AND OTHER OFFICERS.

Frank S. Kedzie, M. S., D. Sc., President; [a] Sept. 15. '80; [b c] Sept. 15, '16.

Jonathan L. Snyder, A. M., Ph. D., LL. D., President Emeritus; [a] Feb. 22, '96; [b c] Sept. 15, '16.

William J. Beal, Ph. D., D. Sc., Emeritus Professor of Botany; [a b] June 9, '70; [c] June 15, '10.

Wilbur O. Hedrick, M. S., Ph. D., Professor of History and Economics; [a b] Aug. 24, '91; [c] June 20, '06.

Herman K. Vedder, C. E., Professor of Civil Engineering; [a b] Sept, 15, '91; [c] July 7, '09.

Walter B. Barrows, B. S., Professor of Zoology and Physiology and Curator of the General Museum; [a b c] Feb. 15, '94.

Rufus H. Pettit, B. S. in Agr., Professor of Entomology; [a] Jan. 1, '97; [b c] Sept. 1, '06.

Addison M. Brown, A. B., Secretary of the College; [a b c] June 1, '02.

Robert S. Shaw, B. S. A., Dean of Agriculture; [a b] Sept. 1, '02; [c] Jan. 15, '08.

Elida Yakeley, Registrar; [a] July 15, '03; [b c] June 1, '08.

Arthur R. Sawyer, B. S., E. E., Professor of Physics and Electrical Engineering; [a b c] April 11, '04.

A. Crosby Anderson, B. S., Professor of Dairy Husbandry; [a] Sept. 1, '05; [b] June 10, '09; [c] June 15, '10.

George W. Bissell, M. E., Dean of Engineering and Professor of Mechanical Engineering; [a b c] June 18, '07.

Ward Giltner, D. V. M., M. S., Professor of Bacteriology and Hygiene; [a b] July 1, '08; [c] June 16, '15.

*Harry J. Eustace, B. S., M. H., Professor of Horticulture; [a b c] Aug. 15, '08.

Victor T. Wilson, M. E., Professor of Drawing and Design; [a b c] Sept. 1, '08.

Walter H. French, M. Pd., M. S., Professor of Agricultural Education; [a b c] Sept. 1, '08.

Vernon M. Shoesmith, B. S., Professor of Farm Crops; [a b c] Feb, 14, '09.

Ernst A. Bessey, Ph. D., Professsor of Botany; [a b c] June 15, '10.

Richard P. Lyman, B. S., D. V. M., Dean of Veterinary Science; Professor of Veterinary Medicine; [a b c] Sept. 28, '10.

*John F. Macklin, Professor of Physical Culture; Director of Athletics; [a b c] March 8, '11.

William W. Johnston, A. M., Professor of English Literature and Modern Languages; [a b c] Sept. 1, '12.

Louis C. Plant, Ph. B., M. S., Professor of Mathematics; [a][b][c] Sept. 1, '13.

Georgia L. White, Ph. D., Dean of Home Economics; [a][b][c] April 1, '14.

Merris M. McCool, Ph. D., Professor of Soils; [a][b][c] July 15, '14.

Alfred K. Chittenden, M. F., Professor of Forestry; [a][b][c] July 15, '14.

Mary E. Edmonds, B. S., Professor of Domestic Science; [a][b][c] Sept. 15, '15.

Lieut. Ira Longanecker, Professor of Military Science and Tactics; [a][b][c] Feb. 1, '16.

Edward H. Ryder, M. A., M. Pd., Associate Professsor of History and Economics; Director of Summer School; [a] Sept. 1, '05; [b] Oct. 21, '09; [c] Jan. 13, '15.

Joseph A. Polson, B. S., M. E., Associate Professor of Mechanical Engineering; [a][b] Sept. 1, '06; [c] July 11, '13.

Arthur J. Clark, A. B., Associate Professor of Chemistry; Director of Band; [a][b] Sept. 1, '06; [c] June 10, '14.

William L. Lodge, B. S., M. A., Associate Professor of Physics; [a][b] Oct. 1, '06; [c] July 21, '15.

Charles P. Halligan, B. S., Associate Professor of Horticulture; [a][b] April 8, '07; [c] June 11, '13.

George D. Shafer, Ph. D., Associate Professor of Entomology; [a] July 1, '08; [b] Sept. 1, '08; [c] July 21, '15.

George A. Brown, B. S., Associate Professor of Animal Husbandry; [a][b] Sept. 1, '08; [c] July 21, '15.

Richard DeZeeuw, Associate Professor of Botany; [a][b] Sept. 1, '09; [c] July 21, '15.

Harry H. Musselman, B. S., Associate Professor of Farm Mechanics; [a][b] Sept. 1, '09; [c] July 21, '15.

Frank W. Chamberlain, B. S., D. V. M., Associate Professor of Comparative Anatomy; [a][b] Jan. 1, '11; [c] July 21, '15.

Ralph C. Huston, M. S., Ph. D., Associate Professor of Chemistry; [a][b] Sept. 1, '11; [c] July 21, '15.

Elam T. Hallman, D. V. M., Associate Professor of Animal Pathology; [a][b] Sept. 1, '12; [c] July 21, '15.

Chace Newman, Assistant Professor of Drawing; [a] Sept. 1, '97; [b][c] Sept. 1, '07.

E. Sylvester King, Assistant Professor of Public Speaking; [a] Jan. 1, '00; [b] Sept. 1, '02; [c] June 10, '14.

Frank H. Sanford, B. S., M. F., Assistant Professor of Forestry; [a][b] Dec. 1, '06; [c] May 1, '09.

Charles W. Chapman, A. B., B. S., Assistant Professor of Physics; [a] Jan. 1, '07; [b][c] Sept. 1, '11.

L. Zae Northrup, B. S., A. M., M. H. E., Assistant Professor of Bacteriology and Hygiene; [a][b] Sept. 1, '07; [c] June 11, '13.

Benjamin B. Roseboom, Jr., B. S., Assistant Professor of Physiology; [a][b] Jan. 15, '09; [c] June 10, '14.

Maurice F. Johnson, B. S., C. E., Assistant Professor of Mathematics; [a][b] April 1, '09; [c] June 11, '13.

Frederick A. Burt, B. S., Assistant Professor of Geology; [a][b] Sept. 1, '09; [c] June 10, '14.

Lloyd C. Emmons, B. S., A. B., Assistant Professor of Mathematics; [a][b] Sept. 1, '09; [c] June 11, '13.

Charles H. Spurway, B. S., M. A., Assistant Professor of Soil Physics; [a,b,c] Sept. 1, '09.

Ernst G. Fischer, Ph. B., Assistant Professor of German; [a] Sept. 1, '10; [b,c] Sept. 1, '14.

John S. McDaniel, B. S., D. V. M., Assistant Professor of Veterinary Medicine and Pharmacology; [a,b] Sept. 1, '11; [c] Feb. 28, '13.

Cyrus A. Melick, D. C. E., Assistant Professor of Civil Engineering; [a,b,c] Sept. 1, '11.

Milton Simpson, M. A., Assistant Professor of English; [a,b] Sept. 1, '11; [c] June 10, '14.

Bruce E. Hartsuch, A. B., Assistant Professor of Chemistry; [a,b] Sept. 1, '11; [c] June 16, '15.

Charles S. Dunford, M. A., Assistant Professor of Economics; [a,b] Sept. 1, '11; [c] June 16, '15.

John P. Hutton, D. V. M., Assistant Professor of Veterinary Surgery; [a,b] Sept. 1, '12; [c] June 1, '13.

Merton M. Cory, B. S., E. E., Assistant Professor of Electrical Engineering; [a,b] Sept. 1, '12; [c] July 21, '15.

Charles B. Mitchell, M. A., Assistant Professor of Public Speaking; [a,b] Sept. 1, '12; [c] June 16, '15.

Ren G. Saxton, B. S., Assistant Professor of Civil Engineering; [a,b] Sept. 1, '13; [c] July 21, '15.

Charles H. Burgess, B. A., Assistant Professor of Poultry Husbandry; [a,b] Oct. 1, '13; [c] May 19, '15.

Joseph F. Cox, B. S. in Agr., Assistant Professsor of Farm Crops; [a,b] Dec. 1, '13; [c] June 16, '15.

Henry T. Darlington, M. S., Assistant Professor of Botany; [a,b,c] July 15, '14.

*Edwin G. Greenman, M. E., Assistant Professor of Mechanical Engineering; [a,b,c] July 15, '14.

Herbert A. Gehring, C. E., Assistant Professor of Civil Engineering; [a,b,c] Sept. 1, '15.

Charles E. Millar, M. S., Assistant Professor of Soils; [a,b,c] Nov. 17, '15.

Lawrence N. Field, B. M. E., Asssistant Professor of Mechanical Engineering; [a,b,c] Feb. 1, '16.

The names of instructors whose resignations took effect between June 30th and Sept. 1st, 1915, do not appear below:

Thomas Gunson, Instructor in Horticulture and Superintendent of Grounds; [a,b] April 1, '91; [c] Sept. 1, '05.

Caroline Holt, Instructor in Drawing, [a,b,c] Sept. 1, '98.

Louise Freyhofer, B. S., Instructor in Music; [a,b,c] Sept. 1, '02.

Norma L. Gilchrist, A. B., Instructor in English; [a,b,c] Sept. 1, '05.

Frank A. Spragg, M. S., Instructor in Farm Crops; [a,b] Dec. 1, '06; [c] Sept. 1, '13.

Mrs. Minnie A. W. Hendrick, A. B., Instructor in History; [a] Sept. 1, '07; [b,c] Sept. 1, '08.

Rose M. Taylor, A. B., M. A., Instructor in Botany; [a,b,c] Feb. 8, '08.

°Mrs. Lillian L. Peppard, Instructor in Domestic Art; [a,b,c] Sept. 1, '08.

William E. Laycock, Instructor in Physics; [a,b,c] Sept. 1, '08.

Andrew Watt, Instructor in Farm Mechanics; [a,b,c] April 1, '09.

Mrs. Antoinette C. Robson, A. B., Instructor in German and English; [a b c] Jan. 1, '09.
Stanley E. Crowe, B. A., Instructor in Mathematics; [a b c] Sept. 1, '09.
Richard H. Reece, B. S., Instructor in Mathematics; [a b c] Jan. 1, '10.
Dewey A. Seeley, B. S., Instructor in Meteorology; [a b c] Mar. 16, '10.
Eugenia I. McDaniel, A. B., Instructor in Entomology; [a b c] April 1, '10.
Sergt. Patrick J. Cross, Instructor in Military Science and Tactics; [a b c] May 1, '10.
°Bertha E. Thompson, A. B., M. A., Instructor in Botany; [a b c] Sept. 1, '10.
Louis B. Mayne, A. B., Instructor in English; [a b c] Sept. 1, '10.
James L. Morse, Instructor in Mechanical Engineering; [a b c] Sept. 1, '10.
Fred Killeen, Director M. A. C. Chorus; [a b c] Sept. 1, '10.
Oren L. Snow, B. S., Instructor in Physics; [a b c] Sept. 1, '10.
George H. Coons, A. M., Ph. D., Instructor in Plant Pathology; [a b c] Jan. 1, '11.
W. Irving Gilson, B. S., M. F., Instructor in Forestry; [a b c] Jan. 1, '11.
Edith W. Casho, Instructor in Physical Culture; Assistant to the Dean; [a b] Sept. 1, '11; [c] June 16, '15.
Rufus P. Hibbard, Ph. D., Instructor in Plant Physiology; [a b c] Sept. 1, '11.
Mabel L. Leffler, Mus. B., Instructor in Music; [a b c] Sept. 1, '12.
Carl E. Newlander, B. S., Instructor in Dairy Manufactures; [a b c] Sept. 1, '12.
Guy G. Speeker, B. S., Instructor in Mathematics; [a b c] Sept. 1, '12.
Allen C. Conger, B. S., M. A., Instructor in Zoology; [a b c] Sept. 1, '12.
Verne E. LeRoy, A. B., M. S., Instructor in Zoology; [a b c] Sept. 1, '12.
Homer E. Dennison, B. S., Instructor in Dairy Husbandry; [a b c] Sept. 1, '12.
William M. Wible, A. M., Instructor in Mathematics; [a b c] Oct. 1, '12.
Stephen V. Klem, Ph. B., M. F., Instructor in Forestry; [a b c] Jan. 1, '13.
Frank E. Millen, B. Sc. A., Instructor in Bee-keeping; [a b c] Sept. 1, '13.
Judson Q. Owen, A. B., Instructor in English; [a b c] Sept. 1, '13.
Claude M. Cade, B. S., C. E., Instructor in Civil Engineering; [a b c] Sept. 1, '13.
Leslie H. Cooledge, B. S., A. M., Instructor in Bacteriology; [a b c] Sept. 1, '13.
Grover C. Woodin, B. S. A., Instructor in Entomology; [a b c] Sept. 1, '13.
Robert E. Loree, B. S., Instructor in Horticulture; [a b c] Sept. 1, '13.
Myron B. Chapin, Instructor in Drawing; [a b c] Sept. 1, '13.
Earl C. Kiefer, B. S., Instructor in Mathematics; [a b c] Sept. 1, '13.
Warren W. Hitchcock, B. S., Instructor in Civil Engineering; [a b c] Sept. 1, '13.
George R. Johnstone, B. A., Instructor in Botany; [a b c] Oct. 1, '13.
Dwight T. Ewing, B. S., Instructor in Chemistry; [a b c] Jan. 1, '14.
Wesley E. Eastman, B. S., Instructor in Zoology; [a b c] Jan. 1, '14.
Alfred Iddles, B. S., Instructor in Drawing; [a b c] April 1, '14.
Edward F. Woodcock, B. S., M. A., Instructor in Botany; [a b c] Sept. 1, '14.
Walter A. Reinert, B. S., in C. E., Instructor in Mathemetics; [a b c] Sept. 1, '14.

Louise I. Clemens, B. S., Instructor in Domestic Science; [a,b,c] Sept. 1, '14.
Walter L. Kulp, A. B., M. S., Instructor in Bacteriology; [a,b,c] Sept. 1, '14.
George M. Grantham, B. S., Instructor in Soils; [a,b,c] Sept. 1, '14.
Corwin C. Armstrong, A. B., Instructor in English; [a,b,c] Sept. 1, '14.
Agnes V. Hatch, B. S., Instructor in Domestic Art; [a,b,c] Sept. 1, '14.
William P. Wood. A. B., Ch. E., Instructor in Chemistry; [a,b,c] Sept. 1, '14.
Frank D. Messenger, B. S., Instructor in Drawing and Design; [a,b,c] Sept. 1, '14.
Lyla D. Edgerton, Mus. B., Instructor in Music; [a,b,c] Sept. 1, '14.
Burt K. Philp, C. E., Instructor in Civil Engineering; [a,b,c] Sept. 1, '14.
William E. J. Edwards, B. S. A., Instructor in Animal Husbandry; [a,b,c] Sept. 1, '14.
Clara K. Morris, B. S., Instructor in Domestic Science; [a,b,c] Sept. 1, '14.
William D. Meltzer, B. S., Instructor in Dairy Manufactures; [a,b,c] Sept. 1, '14.
Dwight C. Carpenter, B. S., Instructor in Chemistry; [a,b,c] Sept. 1, '14.
Francis W. Small, B. S., Instructor in Dairy Husbandry; [a,b,c] Sept. 1, '14.
Alison Ransford, Instructor in Cheese Making; [a,b,c] Jan. 1, '15.
John E. Burnett, B. S., Instructor in Dairy Husbandry; [a,b,c] June 16, '15.
Jesse F. Francis, B. S. A., Instructor in Poultry Husbandry; [a,b,c] July 21, '15.
Henry L. Publow, B. S., Instructor in Chemistry; [a,b,c] Sept. 1, '15.
Joseph W. Stack, B. S., Instructor in Zoology; [a,b,c] Sept. 1, '15.
Arthur L. Bibbins, B. S., Instructor in Farm Crops; [a,b,c] Sept. 1, '15.
Henry I. Davies, B. S., Instructor in Civil Engineering; [a,b,c] Sept. 1, '15.
Charles D. Ball, B. S., Instructor in Chemistry; [a,b,c] Sept. 1, '15.
Leo C. Hughes, A. M., Instructor in French and German; [a,b,c] Sept. 1, '15.
Leon S. Eaton, M. E., Instructor in Mechanical Engineering; [a,b,c] Sept. 1, '15.
Francis L. Schneider, A. M., Instructor in English [a,b,c] Sept. 1, '15.
Willet E. Stark, B. S. in M. E., Instructor in Mechanical Engineering; [a,b,c] Sept. 1, '15.
Kenneth G. Hancher, M. S., Instructor in Chemistry; [a,b,c] Sept. 1, '15.
Theodore E. Friedemann, B. S., Instructor in Chemistry; [a,b,c] Sept. 1, '15.
William N. Clark, B. S. in Agr., Instructor in Animal Husbandry; [a,b,c] Sept. 1, '15.
James B. Hasselman, B. S., Instructor in English; [a,b,c] Sept. 1, '15.
Zella E. Bigelow, Instructor in Domestic Art; [a,b,c] Sept. 1, '15.
Clifford N. Rix, Instructor in Farm Mechanics; [a,b,c] Sept. 1, '15.
Wendell A. Melton, B. S., Instructor in Physics; [a,b,c] Sept. 1, '15.
*Paul L. Miller, M. A., Instructor in Economics; [a,b,c] Sept. 1, '15.
*George T. Hayes, B. S., Instructor in Horticulture; [a,b,c] Sept. 27, '15.
Edna M. Garvin, B. S., Instructor in Domestic Science and Domestic Art; [a,b,c] Oct. 5, '15.

Paul C. Kitchin, B. Sc., Instructor in Botany; [a b] Nov. 1, ’15; [c] Jan. 1, ’16.

Earle H. Stewart, B. S. in M. E., Instructor in Drawing; [a b c] Jan. 1, ’16.

Stanard G. Bergquist, A. B., Instructor in Zoology; [a b c] Jan. 27, ’16.

Linda E. Landon, Librarian; [a b c] Aug. 24, ’91.

Lory F. Newell, Engineer; [a b c] Jan. 1, ’98.

Benjamin A. Faunce, Clerk to President; [a] Sept. 1, ’99; [b c] Apr. 1, ’10.

Rowena Ketchum, Nurse in charge of College Hospital; [a b c] Sept. 1. ’00.

Edwyn A. Bowd, College Architect; [a] Jan. 1, ’02; [b c] Nov. 5, ’13.

Lena M. Maxwell, Assistant Cashier and Bookkeeper; [a] July 1, ’02; [b c] Aug. 1, ’12.

Andrew P. Krentel, Foreman of Woodshop; [a b c] Sept. 1, ’02.

William R. Holmes, Foreman of Forge Shop; [a b c] Sept. 1, ’06.

Jacob Schepers, Cashier; [a b] May 1, ’07; [c] July 1, ’07.

Ralph S. Hudson, B. S., Farm Foreman; [a b c] Dec. 1, ’07.

Maud A. Meech, Chief Clerk to Secretary; [a b] Apr. 1, ’08; [c] Sept. 1, ’10.

*Albert H. Davis, Foreman of the Horticultural Department; [a b c] Sept. 1, ’08.

Edward C. Crawford, Shop Engineer; [a b c] July 1, ’09.

Louise E. Walsworth, Clerk to Secretary; [a b c] Jan. 17, ’10.

Ernest A. Evans, Foreman of Machine Shop; [a b c] Sept. 1, ’10.

Warren S. Robbins, B. S., Assistant in Pathology; [a b] April 1, ’11; [c] July 21, ’15.

°Elizabeth M. Palm, Assistant Librarian; [a b c] July 15, ’11.

Blanche A. Birchard, Clerk to President; [a b c] Aug. 10, ’11.

Charles D. Betts, Purchasing Agent; [a b c] Sept. 1, ’11.

Jay Smith, Assistant in Machine Shop; [a b c] Sept. 1, ’12.

Elijah L. Grover, B. S., Assistant in Agricultural Education; [a b c] Sept. 1, ’13.

Bertha A. Hollister, A. B., State Seed Analyst; [a b c] Sept. 1, ’13.

George H. Peters, Assistant in Pattern Shop; [a b c] Oct. 1, ’13.

Jacob A. Eicher, Foreman of Foundry; [a b c] Sept. 1, ’14.

¶Harry M. Garrison, Assistant in Pattern Shop; [a b c] Sept. 1, ’14.

Frederick O. Ockerblad, B. S., Graduate Assistant in Bacteriology; [a b c] Sept. 1, ’14.

Florence Farwell, House Director, Women’s Building; [a b c] Sept. 1, ’14.

Charles S. Langdon, B. S., Alumni Secretary; [a b c] Sept. 1, ’14.

Anna L. Ferle, Assistant Registrar; [a b c] Oct. 1, ’14.

J. J. Hendryx, Foreman Nursery; [a b c] March 15, ’15.

Eileen Fletcher, Clerk to Secretary; [a b c] June 15, ’15.

Oswald M. Gruzit, B. S., Graduate Assistant in Bacteriology; [a b c] Sept. 1, ’15.

Mancel T. Munn, M. S., Graduate Assistant in Botany; [a b c] Sept. 1, ’15.

I. Forest Huddleson, B. S., Graduate Assistant in Bacteriology; [a b c] Sept. 1, ’15.

Henrik J. Stafseth, B. S., Graduate Assistant in Bacteriology; [a b c] Sept. 1, ’15.

Mrs. Cornelia Lindsay, House Mother, Women’s Building; [a b c] Sept. 1, ’15.

Mrs. Nancy L. Eastman, Matron College Cottage; [a b c] Sept. 1, ’15.

*Frances M. Madison, B. S., Assistant State Seed Analyst; [a,b,c] Sept. 1, '15.

Don C. Heffley, B. S., In charge of Student Employment Bureau and Secretary of Y. M. C. A.; [a,b,c] Sept. 1, '15.

Anna L. Carpenter, Cataloguer and Assistant in Library; [a,b,c] Sept. 1, '15.

Laura M. Trebilcock, B. S., Assistant Librarian, [a,b,c] Sept. 1, '15.

Samuel Toms, Assistant in Farm Mechanics; [a,b,c] Nov. 1, '15.

Eugene Wood, Assistant in Pattern Shop; [a,b,c] Jan. 1, '16.

Louise Mertes, Assistant State Seed Analyst; [a,b,c] Feb. 1, '16.

Eda H. Trickey, Clerk to Secretary; [a,b,c] April 5, '16.

EXPERIMENT STATION WORKERS.

Andrew J. Patten, B. S., Chemist; [a,b,c] Sept. 1, '05.

Charles W. Brown, B. S., Research Assistant in Bacteriology; [a,b,c] Aug. 1, '06.

Charles S. Robinson, M. S., Research Assistant in Chemistry; [a,b,c] Sept. 1, '09.

Myra V. Bogue, Bulletin Clerk, [a,b,c] Jan. 1, '10.

Orrin B. Winter, A. B., Assistant in Chemistry; [a] Feb. 15, '10; [b,c] Sept. 1, '13.

George J. Bouyoucos, Ph. D., Research Assistant in Soils; [a] June 16, '11; [b,c] Sept. 1, '14.

J. Frank Morgan, M. A., Research Assistant in Bacteriology; [a,b,c] Sept. 1, '13.

Walter C. Dutton, B. S., Assistant in Horticulture; [a,b,c] Sept. 1, '13.

Fred T. Riddell, B. S., Assistant in Dairying; [a,b,c] Sept. 1, '13.

Jay H. Muncie, B. A., Assistant in Plant Pathology; [a,b,c] Nov. 17, '13.

Elroy J. Miller, M. S., Assistant in Chemistry; [a,b,c] Sept. 1, '15.

Eugene F. Berger, B. S., Assistant in Chemistry; [a,b,c] Sept. 1, '15.

Robert W. Goss, M. S., Assistant in Plant Pathology; [a,b,c] Oct. 16, '15.

Arthur C. Lytle, B. S., Assistant in Dairying; [a,b,c] Nov. 1, '15.

Hans J. Bock, M. S., Research Assistant in Horticulture; [a,b,c] Jan. 1, '16.

Allen E. Smoll, A. B., Assistant in Chemistry; [a,b,c] Jan. 1, '16.

Eugene E. Down, B. S., Assistant in Farm Crops; [a,b,c] April 1, '16.

°Absent on leave.
*Resigned.
¶Deceased.
a First appointment.
b Present appointment.
c Present title.

AGRICULTURAL EXPERIMENT STATION

OF THE

MICHIGAN AGRICULTURAL COLLEGE

(Under the control of the State Board of Agriculture.)

STATION COUNCIL.

Frank S. Kedzie, D. Sc., President *Ex-officio*.
Robert S. Shaw, B. S. A., Director.
Ward Giltner, D. V. M., M. S., Bacteriologist.
°Harry J. Eustace, B. S., Horticulturist.
Alfred K. Chittenden, M. F., Forester.
A. Crosby Anderson, B. S., Dairy Husbandman.
Rufus H. Pettit, B. S. A., Entomologist.
Andrew J. Patten, B. S., - Chemist.
Merris M. McCool, Ph. D., Soil Physicist.
Ernst A. Bessey, Ph. D., - Botanist.
Vernon M. Shoesmith, B. S., Farm Crops Experimenter.

Addison M. Brown, Secretary.

ADVISORY AND ASSISTANT STAFF.

Charles P. Halligan, B. S., Asso. Horticulturist.
Elroy J. Miller, M. S., Asst. in Chemistry.
George A. Brown, B. S., Asso. Animal Husbandman.
George D. Shafer, Ph. D., Research Asst. in Entomology.
Charles W. Brown, B. S., Research Asst. in Bacteriology.
Fred T. Riddell, B. S., - Asst. in Dairying.
Rufus P. Hibbard, Ph. D., Research Asst. in Plant Physiology.
George H. Coons, A. B., A. M., Research Asst. in Plant Pathology.
Harry H. Musselman, B. S., Asso. in Farm Mechanics.
Charles H. Burgess, A. B., Asst. Poultry Husbandman.
Eugene F. Berger, B. S., Asst. in Chemistry.
Frank A. Spragg, M. S., - Research Asst. in Farm Crops (Plant Breeding.)
Allen E. Smoll, A. B., Asst. in Chemistry.
Hans J. Bock, M. S., Research Asst. in Horticulture.
L. Zae Northrup, B. S., Asst. Bacteriologist.
Linda E. Landon, - - Librarian.
Charles S. Robinson, M. S., Research Asst. in Chemistry.
James F. Morgan, M. A., Research Asst. in Bacteriology.
Orrin B. Winter, A. B., Asst. in Chemistry.
Eugenia I. McDaniel, A. B., Asst. in Entomology.
Walter C. Dutton, B. S., Asst. Horticulturist.
Leslie H. Cooledge, A. M., Research Asst. in Bacteriology
L. Coleman Ludlum, M. S., Asst. in Bacteriology.
Jay H. Muncie, B. A., Asst. in Plant Pathology.
Grover C. Woodin, B. S. A., Asst. in Entomology.
George J. Bouyoucos, Ph. D., Research Asst. in Soils.
Robert W. Goss, M. S., Asst. in Plant Pathology.
Myra V. Bogue, - - Bulletin Clerk.

°Absent on leave.

STANDING COMMITTEE IN CHARGE.

William H. Wallace - - - - - - - - - - Saginaw.
Alfred J. Doherty - - - - - - - - - - Clare.

STATE WEATHER SERVICE.

(Under the control of the State Board of Agriculture.)

OFFICER OF THE SERVICE.

Director, - - - - - - C. F. Schneider, U. S. Weather Service.

CO-OPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS

Michigan Agricultural College and United States Department of Agriculture Co-operating.

ADMINISTRATION.

Frank Stewart Kedzie, D. Sc.	President.
Robert James Baldwin, B. S.	Director of Extension Work.

EXTENSION SPECIALISTS.

Representing the several departments of the College.

William Franklin Raven	Ext. Representative in Upper Peninsula.
James Wade Weston, B. S.	Assistant in Upper Peninsula.
Ivan Karl Maystead, B. S.	Ext. Specialist in Farm Crops.
John Whitley Nicolson, B. S.	Ext. Specialist in Farm Crops.
John Henry Carmody, B. S.	Ext. Specialist in Horticulture.
Clarence William Waid, B. S.	Ext. Specialist in Potatoes and Vegetables.
Charles Philo Reed, M. Agr.	Ext. Farm Management Demonstrator.
Paulina Elona Raven, M. S.	Ext. Specialist in Home Economics.
Margaret M. Justin, B. S.	Ext. Specialist in Home Economics.
Anna Bryant Cowles, B. S.	Assistant in Home Economics.
Orsel Edwin Robey, B. S.	Ext. Specialist in Household Engineering.
Don Bion Whelan, M. S.	Ext. Specialist in Control of Insect Pests.
James Aaron Waldron, B. S.	Ext. Specialist in Live Stock.
E. Lynn Grover, B. S.	Ext. Representative of Agrl. Education.
*Comfort A. Tyler	Ext. Representative in Forestry.

COUNTY AGRICULTURAL AGENTS.

Eben Mumford, Ph. D.	State Leader.
Charles Benjamin Cook, B. S.	Assistant State Leader.
Roy Gabriel Hoopingarner, B. S.	Iron.
Earl Paul Robinson, B. S.	Saginaw.
Harvey George Smith, B. S. A.	Kent.
Jason Woodman, B. S.	Kalamazoo.
Julius William Chapin, B. S.	Branch.
Harry B. Blandford	Newaygo.
Leo M. Geismar	Houghton.
James Francis Zimmer, M. S.	Wexford.
James Frank Kadonsky, B. S.	Gogebic.
John Martin Wendt, B. S.	St. Joseph.
Clark Louis Brody, B. S.	St. Clair.
Lee Roy Walker, B. S.	Marquette.
Clinton Vede Ballard, B. S.	Dickinson.

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*Resigned.

Curtis Linden Coffeen, B. S.	Lenawee.
Roswell Gilbert Carr, B. S.	Ontonagon.
Carl Henry Knopf, B. S.	Cheboygan.
Deloy Lesly Hagerman, B. S.	Ottawa.
Leslie Olds	Muskegon.
Russell Vaughan Tanner, B. S.	Mason.
Theodore Austin Farrand	Van Buren.
David Woodman	Alpena.
Alfred Bentall	Allegan.
Harry J. Lurkins	Berrien.

BOYS' AND GIRLS' CLUB WORK.

Eduard Christian Lindemann, B. S.	State Agent.

MARKETS.

James Nathan McBride	Director.

FARMERS' INSTITUTES.

Levi Rawson Taft, M. S.	Superintendent.

ACCOUNTS OF

THE MICHIGAN AGRICULTURAL COLLEGE

FOR THE YEAR ENDING JUNE 30, 1916

SECRETARY'S FINANCIAL REPORT

				Dr.	Cr.
July 1, 1915.	Cash on hand			$3,436 09	
July 1, 1915.	Cash on deposit, College Treasurer			6,895 87	
June 30, 1916.	To special appropriation receipts			173,603 64	
	From State Treasurer		$88,830 00		
	From U. S. Treasurer		58,032 37		
	From gifts, R. E. Olds		10,000 00		
	From institution and other sources		16,741 27		
June 30, 1916.	By disbursements				$150,349 27
	Special appropriations		$29,442 05		
	Experiment Station		57,881 53		
	Extension		63,025 69		
June 30, 1916.	To current account receipts			655,155 02	
	From State Treasurer, land grant interest		$71,391 56		
	From State Treasurer, one-fifth mill tax		362,170 00		
		$560,000 00			
	(a)	197,830 00			
	From U. S. Treasurer, Morrill Fund		50,000 00		
	From institution and other sources		167,648 34		
	From So. Haven Exp. Station		233 02		
	From U. P. Experiment Station		3,712 10		
	By general account disbursements				651,097 47
	From current account		$630,173 34		
	From supplementary accounts		20,924 13		
June 30, 1916.	By cash on hand				1,179 25
June 30, 1916.	By cash on deposit				36,464 63
				$839,090 62	$839,090 62

(a)		
(a)	Appropriated for Extension	$32,275 00
	Appropriated for Exp. Station	15,555 00
	Appropriated for Gymnasium	150,000 00

TABLE NO. 1.—*Tabular exhibit of Secretary's report.*

	Balance sheet, July 1, 1915.		Transactions July 1, 1915 to June 30, 1916.		Balance sheet, June 30, 1916.	
	Dr.	Cr.	Dr.	Cr.	Dr.	Cr.
Cash	$3,436 09		$2,256 84		$1,179 25	
College Treasurer*	6,895 87			$29,568 76	36,464 63	
Special appropriation		$2,960 99	173,603 64	150,349 27		$26,215 36
Current accounts		7,370 97	651,209 90	630,173 34		11,428 52
Supplementary accounts			3,945 12	20,924 13		
Totals	$10,331 96	$10,331 96	$831,015 50	$831,015 50	$37,643 88	$37,643 88

*Treasurer's statement is greater July 1, 1915, by $8,368.09 and June 30, 1916, by $29,169.71; warrants outstanding.

TREASURER'S ACCOUNT.

	Dr.	Cr.
Balance on hand July 1, 1915	$15,263 96	
Receipts from State Treasurer, and Secretary of College	829,498 09	
Interest on deposits during year	1,517 41	
Warrants paid July 1, 1915, to June 30, 1916		$780,645 12
Balance on hand June 30, 1916		65,634 34
Total	$846,279 46	$846,279 46

TABLE NO. 2.—*Statement of special appropriation accounts for the fiscal year ending June 30, 1916.*

	Balance of accounts, July 1, 1915.		Receipts during fiscal year.		Total available.	Total expended.	Balance of accounts, June 30, 1916.	
	Dr.	Cr.	From State Treasurer.	From institution and other sources.			Dr.	Cr.
						$5,949 00	$5,949 00	
Engineering shops	....	$2,317 68	*$30,000 00	$30,721 82	$63,039 50	57,881 53	....	$5,157 97
Experiment Station	....	....	†60,307 37	10 45	60,317 82	63,025 69	2,707 87	....
Extension	....	....	40,000 00	....	40,000 00	16,063 58	....	23,936 42
Gymnasium	....	....	‡10,000 00	....	10,000 00	4,934 19	....	5,065 81
Hall of Engineering	....	....	....	1,539 00	1,539 00	1,539 00	....	....
Nursery licenses and inspection	....	465 65	....	....	465 65	....	....	465 65
Sundry improvements	....	12 20	....	25 00	37 20	25 00	....	12 20
Sayer Fund	....	165 46	1,000 00	....	1,165 46	931 28	....	234 18
Weather Bureau	....							
Totals	....	$2,960 99	$141,307 37	$32,296 27	$176,564 63	$150,349 27	$8,656 87	$34,872 23

*United States Treasurer.
†$28,032.37, United States Treasurer.
‡Gift, R. E. Olds.

TABLE NO. 3.—*William Smith Sayer Scholarship Fund.*

Fund.	Year ending June 30.	Income.	Income expended to.	Amount.	Balance including principal.
$500.00 received of F. F. Sayer, administrator of the estate of William Smith Sayer, to establish Scholarship in Bacteriology....................	1910	$32 25	A. McVittie....	$19 75	$512 50
	1911	37 50	....	....	550 00
	1912	12 50	D. K. Fisher...	25 00	512 50
			H. K. Wright..	25 00	
	1913	25 00	D. Francisco...	25 00	512 50
	1914	24 85	R. W. Waffle...	25 00	512 35
	1915	24 85	J. D. Baker....	25 00	512 20
	1916	25 00	J. M. Maze....	25 00	512 20
Total........................	....	$181 95	....	$169 75	....

TABLE NO. 4.—*Current Account, July 1, 1915, to June 30, 1916.*

On account of—	Dr. To disbursements.	Cr. By receipts.
U. S. Treasurer, 26th annual payment under act of Congress of August, 1890	....	$50,000 00
State Treasurer, one-fifth mill fund	....	362,170 00
State Treasurer, interest on proceeds of sales of U. S. land grant	....	71,391 56
Advertising	$3,280 08	....
Agricultural Education	1,225 55	....
Animal Husbandry	11,171 52	7,911 79
Athletics	3,370 25	1,447 05
Bacteriology	8,882 48	6,693 33
Botany	5,670 68	364 63
Chemistry	13,407 88	7,350 35
Civil Engineering	3,247 72	678 75
Cleaning	3,984 75	1,234 54
College Extension	87 71	....
Contingent Building	93,244 48	42,820 42
Diploma fees, $1,345.00; incidentals, $11,049.00; matriculation, $2,965.00; room rent, $13,056.07; tuition, $3,937.50; delinquent, $446.00; sundry, $10,021.85.		
Crops	1,902 96	406 76
Dairy Husbandry	51,137 62	50,284 04
Dean's Office	1,702 65	....
Dean of Summer School	693 40	....
Drawing	550 45	6 00
Electric Lighting	7,225 81	2,371 59
English	684 70	54 00
Entomology	1,225 78	62 10
Farm and Horses	20,084 92	12,450 76
Farm Management	61 29	....
Farm Mechanics	2,648 93	1,208 41
Forestry	4,362 77	1,907 79
Freight and Cartage	2,332 65	4 62
Heating	32,308 13	645 63
History	239 72	92 00
Home Economics	10,180 85	2,654 32
Horticulture	7,381 42	829 35
Hospitals	1,989 63	309 53
Library	3,679 12	8 36
Mathematics	433 21	165 00
Mechanical Engineering	11,471 20	2,153 63
Meteorology	100 73	22 00
Military Science	2,164 74	11 50
Miscellaneous	7,379 46	3,566 60
Office, President's	1,316 16	183 84
Office, Secretary's	4,758 30	1,937 13
Physics and Electrical Engineering	4,371 13	585 43
Poultry	4,438 98	1,702 46
Registrar	3,848 81	21 88
Salaries	268,789 49	2,334 39
Seed Analysis	182 60	254 73
Soils	3,512 17	254 33
Special Courses	3,542 41	2,167 50
Telephones	1,219 73	347 10
Veterinary Science	4,188 05	967 47
Zoological	2,847 17	1,085 00
Anatomy	1,442 16	346 98
Pathology	6,200 94	7,745 25
Totals	$630,173 34	$651,209 90
Supplementary accounts:		
Bulletins	$7,058 86	....
Farmers' Institutes	74 36	....
South Haven Experiment Station	2,650 63	$233 02
Upper Peninsula Experiment Station	11,140 28	3,712 10
Balance beginning fiscal year, July 1, 1915	....	7,370 97
Balance beginning fiscal year, July 1, 1916	11,428 52	....
Totals	$662,525 99	$662,525 99

TABLE NO. 5.—*Experiment Station account for fiscal year ending June 30, 1916.*

	Disbursements.			Dr. Total disbursements each department.	Cr. By receipts.
	Adams.	Hatch.	State.		
Balance July 1, 1915					$2,317 68
U. S. Treasurer for fiscal year					30,000 00
Fertilizer fees					5,840 00
Commercial Feed Stuffs					8,705 00
Apportionment from one-fifth mill fund					15,555 00
Animal Husbandry			$766 80	$766 80	308 37
Bacteriological	$2,423 97	$317 84	801 84	3,543 65	
Botanical	1,016 08	442 65	1,829 50	3,288 23	59 25
Bulletin Clerk			29 99	29 99	
Chemical	780 65	995 57	4,409 86	6,186 08	46 49
Dairy			566 78	566 78	
Director's Office		357 53	494 48	852 01	4 29
Entomological	12 10	259 14	8 11	279 35	
Farm		1,076 08	1,416 15	2,492 23	203 18
Horticultural		980 87	337 46	1,318 33	
Library		435 74	37 64	473 38	
Live Stock			36 17	36 17	
Salaries	10,093 80	9,476 90	17,055 40	36,626 10	
Secretary's Office			51 35	51 35	24
Soils	673 40	657 68	40 00	1,371 08	
Balance June 30, 1916				5,157 97	
Total	$15,000 00	$15,000 00	$27,881 53	$63,039 50	$63,039 50

TABLE NO. 6.—*Extension Account for fiscal year ending June 30, 1916.*

On account of projects.	Disbursements.			Dr. Total disbursements for each project.	Cr. By receipts.
	Lever.	Lever State.	State.		
U. S. Treasurer for fiscal year					$28,032 37
Apportioned from one-fifth mill fund, Lever State					*15,000 00
Apportioned from one-fifth mill fund, State					17,275 00
Miscellaneous					10 45
Administration	$2,421 60	$1,562 10	$292 10	$4,275 80	
County Agents	12,335 84	997 56	379 81	13,713 21	
Home Economics	2,663 06	1,161 31	363 90	4,188 27	
Movable Schools		1,696 66		1,696 66	
Boys' and Girls' Club Work	566 70	2,096 55	346 20	3,009 45	
Farm Crops	1,613 20	1,915 48	526 88	4,055 56	
Live Stock	353 80	501 69	378 15	1,233 64	
Horticulture	1,416 61	386 78	217 23	2,020 62	
Potatoes and vegetables	1,601 25	935 74	250 14	2,787 13	
Upper Peninsula	2,552 50	2,445 39	791 66	5,789 55	
Farm management demonstration	844 06	1,071 88	66 52	1,982 46	
Control of insect pests	596 45	458 86	82 42	1,137 73	
Household engineering	1,067 30	329 36	107 96	1,504 62	
Country life conference			241 56	241 56	
Dairy husbandry			11 41	11 41	
Fairs and trains			178 80	178 80	
Forestry			1,480 14	1,480 14	
Institutes			11,155 47	11,155 47	
Markets			2,521 84	2,521 84	
Soils			41 77	41 77	
Balance overdrawn, June 30, 1916					2,707 87
Totals	$28,032 37	$15,559 36	$19,433 96	$63,025 69	$63,025 69

*Vouchers on file from counties for $3,032.37 as offset to Smith-Lever fund.

TABLE NO. 7.—*Positions and salaries as shown by pay roll dated June 30, 1916.*

Grade.	Rate per year.	Classification.		Extension.
		Current.	Experiment station.	
Administration and Miscellaneous:				
President's Office:				
President	$6,500 00	$6,500 00		
President Emeritus	2,500 00	a2,500 00		
Clerk	1,400 00	1,400 00		
Stenographer	850 00	850 00		
Secretary's Office:				
Secretary	2,200 00	b1,500 00	$700 00	
Cashier	1,900 00	1,700 00	200 00	
Bookkeeper	1,000 00	900 00	100 00	
Chief Clerk	1,100 00	975 00	125 00	
Purchasing Agent	2,000 00	2,000 00		
Clerk	850 00	850 00		
Clerk	550 00	550 00		
Clerk	600 00	600 00		
Registrar's Office:				
Registrar	1,500 00	1,500 00		
Clerk	800 00	800 00		
Assistant to Registrar	1,500 00	1,500 00		
Institute and Nursery Inspection:				
Superintendent	2,300 00	a700 00		$1,600 00
Library:				
Librarian	1,400 00	1,280 00	120 00	
Cataloguer and Assistant	800 00	800 00		
Assistant Librarian	700 00	700 00		
Miscellaneous:				
Engineer	1,300 00	1,300 00		
Night Watchman	650 00	650 00		
Nurse	500 00	500 00		
Architect	4,540 00	4,540 00		
Stenographer	700 00	700 00		
Stenographer	700 00	350 00	350 00	
Stenographer	480 00	480 00		
Stenographer	480 00	480 00		
Stenographer	600 00	330 00	270 00	
Stenographer	600 00	600 00		
Stenographer	600 00	600 00		
Stenographer	590 00	590 00		
Stenographer	550 00	550 00		
Stenographer	550 00	550 00		
Stenographer	550 00	550 00		
Stenographer	600 00	600 00		
Secretary Y. M. C. A.	500 00	500 00		
Director M. A. C. Chorus	500 00	500 00		
Instructor Meteorology	350 00	350 00		
Division of Home Economics:				
Dean	2,500 00	c2,500 00		
Department of Domestic Art:				
Instructor	1,200 00	c1,200 00		
Instructor	850 00	c850 00		
Instructor	700 00	c700 00		
Department of Domestic Science:				
Professor	1,500 00	c1,500 00		
Instructor	850 00	c850 00		
Instructor	700 00	c700 00		
Instructor	800 00	c800 00		
Instructor Music	1,200 00	1,200 00		
Assistant Instructor Music	750 00	c750 00		
Assistant Instructor Music	600 00	c600 00		
House Mother	800 00	c800 00		
Asst. to Dean and Instructor Physical Culture	900 00	c900 00		
Matron	500 00	c500 00		
House Director	850 00	c850 00		
Division of Engineering.—Dean's Office:				
Dean	3,500 00	a3,500 00		
Clerk	600 00	600 00		

TABLE NO. 7.—*Continued.*

Grade.	Rate per year.	Classification		Extension.
		Current.	Experiment station.	
Department of Drawing and Design:				
Professor	$2,500 00	$2,500 00		
Assistant Professor	1,600 00	1,600 00		
Instructor	1,000 00	1,000 00		
Instructor	1,100 00	1,100 00		
Instructor	950 00	950 00		
Instructor	1,000 00	1,000 00		
Instructor	850 00	850 00		
Department of Civil Engineering:				
Professor	2,500 00	a2,500 00		
Assistant Professor	1,900 00	1,900 00		
Assistant Professor	1,700 00	1,700 00		
Instructor	1,500 00	1,500 00		
Instructor	1,500 00	1,500 00		
Instructor	1,300 00	1,300 00		
Instructor	1,300 00	1,300 00		
Instructor	900 00	900 00		
Department of Mechanical Engineering:				
Associate Professor	2,300 00	2,300 00		
Assistant Professor	1,800 00	1,800 00		
Instructor	1,400 00	1,400 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Instructor	750 00	750 00		
Instructor	750 00	750 00		
Foreman Machine Shop	1,200 00	1,200 00		
Instructor	900 00	900 00		
Foreman Pattern Shop	1,200 00	1,200 00		
Foreman Foundry	1,000 00	1,000 00		
Foreman Forge Shop	1,000 00	1,000 00		
Shop Engineer	780 00	780 00		
Department of Physics and Electrical Engineering:				
Professor	2,800 00	2,800 00		
Assistant Professor	2,000 00	2,000 00		
Assistant Professor	1,900 00	1,900 00		
Instructor	1,500 00	1,500 00		
Instructor	1,400 00	1,400 00		
Instructor	1,300 00	1,300 00		
Instructor	850 00	850 00		
Division of Science and Letters:				
Department of Bacteriology:				
Professor	2,500 00	1,800 00	$700 00	
Assistant Professor	1,500 00	1,250 00	250 00	
Instructor	1,500 00	650 00	850 00	
Research Assistant in Bacteriology	1,100 00	1,100 00		
Assistant in Bacteriology	1,200 00	500 00	700 00	
Research Assistant in Bacteriology	1,800 00		1,800 00	
Research Assistant in Bacteriology	1,500 00		1,500 00	
Graduate Assistant in Bacteriology	400 00	400 00		
Graduate Assistant in Bacteriology	400 00	400 00		
Graduate Assistant in Bacteriology	200 00	200 00		
Graduate Assistant in Bacteriology	200 00	200 00		
Department of Botany:				
Professor	2,500 00	a2,300 00	200 00	
Assistant Professor	1,800 00	1,800 00		
Assistant Professor	1,500 00	1,500 00		
Instructor	1,200 00	1,200 00		
Research Assistant in Plant Pathology	1,800 00	750 00	1,050 00	
Research Assistant in Plant Physiology	1,800 00	800 00	1,000 00	
Instructor	1,100 00	1,100 00		
Instructor	1,100 00	1,100 00		
Instructor	1,300 00	1,300 00		
Instructor	1,080 00	1,080 00		
Instructor	400 00	400 00		
Assistant in Plant Pathology	1,300 00		1,300 00	
Assistant in Plant Pathology	500 00		500 00	

TABLE NO. 7.—*Continued.*

Grade.	Rate per year.	Classification.		Extension.
		Current.	Experiment station.	
Department of Chemistry:				
Professor	$2,300 00	$2,300 00		
Associate Professor	2,000 00	2,000 00		
Assistant Professor	1,300 00	1,300 00		
Instructor	1,200 00	1,200 00		
Instructor	1,150 00	1,150 00		
Instructor	1,100 00	1,100 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Instructor	900 00	900 00		
Instructor	850 00	850 00		
Department of English:				
Professor	2,500 00	a2,500 00		
Assistant Professor	1,700 00	1,700 00		
Assistant Professor	1,600 00	1,600 00		
Assistant Professor	1,500 00	1,500 00		
Instructor	1,400 00	1,400 00		
Instructor	1,200 00	1,200 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Instructor	900 00	900 00		
Instructor	1,200 00	1,200 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Department of Entomology:				
Professor	2,500 00	a2,100 00	$400 00	
Assistant Professor	2,200 00	400 00	1,800 00	
Instructor	1,200 00	950 00	250 00	
Instructor	1,100 00	600 00	500 00	
Instructor	1,300 00	650 00		$650 00
Inspector Apiaries	400 00	400 00		
Department of History:				
Professor	2,800 00	2,800 00		
Associate Professor	2,800 00	2,800 00		
Instructor	1,300 00	1,300 00		
Instructor	900 00	900 00		
Department of Mathematics:				
Professor	2,800 00	2,800 00		
Assistant Professor	1,900 00	1,900 00		
Assistant Professor	1,500 00	1,500 00		
Instructor	1,300 00	1,300 00		
Instructor	1,400 00	1,400 00		
Instructor	1,300 00	1,300 00		
Instructor	1,250 00	1,250 00		
Instructor	1,200 00	1,200 00		
Instructor	1,250 00	1,250 00		
Department of Military Science:				
Sergeant	1,000 00	1,000 00		
Department of Zoology:				
Professor	2,500 00	a2,500 00		
Assistant Professor	1,500 00	1,500 00		
Assistant Professor	1,500 00	1,500 00		
Instructor	1,400 00	1,400 00		
Instructor	1,200 00	1,200 00		
Instructor	1,000 00	1,000 00		
Instructor	960 00	960 00		
Instructor	1,100 00	1,100 00		
Division of Veterinary Science:				
Dean	3,300 00	3,300 00		
Assistant Professor	2,100 00	2,100 00		
Assistant Professor	2,100 00	2,100 00		
Assistant Professor	1,800 00	1,800 00		
Instructor	1,800 00	1,800 00		
Instructor	1,700 00	1,700 00		
Division of Agriculture:				
Dean	3,800 00	a2,300 00	1,500 00	

TABLE NO. 7.—*Continued.*

Grade.	Rate per year.	Classification.		Extension.
		Current.	Experiment station.	
Department of Agricultural Education:				
Professor	$2,800 00	$2,800 00		
Instructor	1,700 00	1,700 00		
Department of Animal Husbandry:				
Assistant Professor	2,000 00	1,800 00	$200 00	
Instructor	1,650 00	1,650 00		
Instructor	1,000 00	1,000 00		
Department of Dairy Husbandry:				
Professor	2,800 00	2,600 00	200 00	
Instructor	1,600 00	1,600 00		
Instructor	1,500 00	1,500 00		
Instructor	1,200 00	1,200 00		
Instructor	1,100 00	1,100 00		
Instructor	900 00	900 00		
Instructor in Cheese-making	720 00	720 00		
Clerk	700 00	700 00		
Assistant in Dairying	900 00		900 00	
Assistant in Dairying	1,050 00		1,050 00	
Department of Poultry Husbandry:				
Assistant Professor	1,400 00	1,200 00	200 00	
Instructor	900 00	900 00		
Department of Farm Crops:				
Professor	2,800 00	2,500 00	300 00	
Instructor	1,700 00	1,700 00		
Expert in Plant Breeding	1,950 00	450 00	1,500 00	
Instructor	1,000 00	1,000 00		
Research Assistant	900 00		900 00	
Department of Farm and Horses:				
Foreman	1,400 00	1,400 00		
Department of Farm Mechanics:				
Assistant Professor	2,000 00	1,650 00	350 00	
Instructor	1,000 00	1,000 00		
Instructor	800 00	800 00		
Instructor	780 00	780 00		
Department of Forestry:				
Professor	2,800 00	2,600 00	200 00	
Assistant Professor	2,000 00	2,000 00		
Instructor	1,800 00	1,800 00		
Instructor	1,800 00	1,800 00		
Instructor	750 00	750 00		
Department of Horticulture:				
Professor	3,000 00	2,100 00	900 00	
Associate Professor	2,400 00	2,100 00	300 00	
Instructor	1,600 00	1,600 00		
Instructor	1,350 00	1,350 00		
Research Assistant in Horticulture	1,200 00		1,200 00	
Assistant in Horticulture	1,500 00		1,500 00	
Department of Soils:				
Professor	2,800 00	2,200 00	600 00	
Assistant Professor	1,750 00	1,750 00		
Instructor	1,700 00	1,700 00		
Instructor	1,350 00	1,350 00		
Research Assistant in Soils	2,200 00		2,200 00	
Chemistry Division, Exp. Station:				
Chemist	2,800 00		2,800 00	
Research Assistant in Chemistry	2,000 00		2,000 00	
Assistant in Chemistry	1,600 00		1,600 00	
Assistant in Chemistry	1,100 00		1,100 00	
Assistant in Chemistry	1,000 00		1,000 00	
Assistant in Chemistry	900 00		900 00	
Bulletin Clerk	660 00		660 00	
Division of Extension:				
Administration:				
Director	2,000 00			$2,000 00
Clerk	600 00			600 00

TABLE NO. 7.—*Concluded.*

Grade.	Rate per year.	Classification.		Extension.
		Current.	Experiment station	
County Agents:				
State Leader	$800 00			$800 00
Assistant State Leader	600 00			600 00
Assistant Kent County	700 00			700 00
Assistant Gogebic County	600 00			600 00
Assistant Houghton County	600 00			600 00
Assistant Iron County	600 00			600 00
Assistant Alpena County	600 00			600 00
Assistant Newaygo County	600 00			600 00
Assistant St. Clair County	600 00			600 00
Assistant Saginaw County	600 00			600 00
Assistant Berrien County	1,200 00			1,200 00
Assistant Wexford County	600 00			600 00
Assistant St. Joseph County	600 00			600 00
Assistant Marquette County	600 00			600 00
Assistant Dickinson County	600 00			600 00
Assistant Lenawee County	600 00			600 00
Assistant Cheboygan County	600 00			600 00
Assistant Ontonagon County	600 00			600 00
Assistant Ottawa County	1,200 00			1,200 00
Assistant Van Buren County	1,200 00			1,200 00
Assistant Mason County	1,200 00			1,200 00
Assistant Muskegon County	1,200 00			1,200 00
Assistant Allegan County	600 00			600 00
Home Economics:				
Leader	1,500 00			1,500 00
Assistant	800 00			800 00
Assistant	1,000 00			1,000 00
Boys' and Girls' Clubs:				
Leader	600 00			600 00
Farm Crops:				
Specialist	1,200 00			1,200 00
Specialist	1,000 00			1,000 00
Horticulture:				
Specialist	2,000 00			2,000 00
Potatoes and Vegetables:				
Specialist	1,800 00			1,800 00
Upper Peninsula:				
Leader	2,000 00			2,000 00
Assistant	1,200 00			1,200 00
Farm Management:				
Demonstrator	500 00			500 00
Household Engineering:				
Specialist	1,200 00			1,200 00
Live Stock:				
Specialist	1,400 00			1,400 00
Markets:				
Specialist	1,800 00			1,800 00
Assistant	1,500 00			1,500 00
Total	$349,170 00	$268,995 00	$38,725 00	$41,450 00

(a) House.
(b) Other sources, $1,000.00. House.
(c) Use of rooms.

TABLE NO. 8.—*Salaries experiment station, fiscal year ending June 30, 1916.*

Director	$1,499 60
Bacteriologist	700 00
Assistant Bacteriologist	250 00
Research Assistant in Bacteriology	126 40
Research Assistant in Bacteriology	850 00
Research Assistant in Bacteriology	1,800 20
Research Assistant in Bacteriology	1,474 60
Assistant in Bacteriology	269 60
Assistant in Bacteriology	350 00
Botanist	200 00
Research Assistant in Botany	1,000 00
Assistant in Botany	1,050 10
Assistant in Plant Pathology	1,283 20
Assistant in Plant Pathology	542 60
Chemist	2,715 60
Research Assistant in Chemistry	1,974 80
Assistant Chemist	450 00
Assistant in Chemistry	1,583 20
Assistant in Chemistry	151 60
Assistant in Chemistry	914 60
Assistant in Chemistry	831 60
Entomologist	400 00
Research Assistant in Entomology	1,800 00
Assistant in Entomology	250 50
Assistant in Entomology	500 00
Dairy Husbandman	200 00
Assistant in Dairy Husbandry	1,033 10
Assistant in Dairy Husbandry	599 20
Animal Husbandman	200 00
Farm Crops Experimenter	300 00
Assistant in Farm Crops	301 60
Expert in Plant Breeding	1,500 00
Soil Physicist	600 00
Research Assistant in Soils	2,124 20
Horticulturist and Vice Director	899 80
Assistant Horticulturist	300 00
Assistant in Horticulture	1,474 80
Assistant in Horticulture	600 00
Forester	200 00
Farm Mechanics	350 00
Poultry Husbandman	200 00
Inspector of Fertilizers	250 00
Librarian	120 00
Secretary	700 20
Cashier	200 00
Bookkeeper	100 00
Stenographer	125 00
Stenographer	350 00
Stenographer	270 00
Bulletin Clerk	660 00
Total	$36,626 10

TABLE NO. 9.—*Salaries Extension—Lever Fund for fiscal year ending June 30, 1916.*

Administration Director	$1,932 60
Clerk	499 00
State Leader, County Agents	800 00
Assistant State Leader, County Agents	551 00
County Agent, Kent County	650 00
County Agent, Branch County	524 23
County Agent, Gogebic County	600 00
County Agent, Houghton County	600 00
County Agent, Iron County	600 00
County Agent, Kent County	234 00
County Agent, Alpena County	169 78
County Agent, Newaygo County	600 00
County Agent, St. Clair County	600 00
County Agent, Saginaw County	600 00
County Agent, Wexford County	600 00
County Agent, St. Joseph County	600 00
County Agent, Marquette County	600 00
County Agent, Dickinson County	600 00
County Agent, Lenawee County	513 63
County Agent, Cheboygan County	350 50
County Agent, Ontonagon County	368 52
County Agent, Ottawa County	600 00
County Agent, Van Buren County	402 20
County Agent, Mason County	450 00
County Agent, Muskegon County	402 20
County Agent, Allegan County	118 68
County Agent, Berrien County	201 10
Leader, Home Economics	1,466 20
Assistant Leader, Home Economics	793 56
Assistant in Home Economics	665 20
Leader, Boys' and Girls' Club Work	466 20
Leader, Boys' and Girls' Club Work	150 00
Farm Crops' Specialist	296 70
Farm Crops' Specialist	497 80
Farm Crops' Specialist	1,000 00
Leader, Institutes	1,330 40
Specialist, Horticulture	834 30
Specialist, Horticulture	708 82
Specialist, Potatoes and Vegetables	1,749 60
Representative in Upper Peninsula	2,000 00
Representative in Upper Peninsula	816 20
Farm Management Demonstrator	500 00
Clerk	385 26
Specialist, Entomology	650 00
Leader, Household Engineering	1,166 20
Field Agent, Forestry	997 30
Specialist, Live Stock	469 20
Director, Markets	1,051 60
Assistant Director, Markets	251 40
Institute Workers and Others	7,709 30
Total	$40,722 68

TABLE NO. 10.—*Income of the Michigan Agricultural College from all outside sources from the date of its foundation to the present time.*

Year.	From State Legislature.			From U. S. Congress.				Total.
	For current expenses.	For special purposes.	Land sales, salt spring and swamp land grants.	Morrill act of 1862, interest from land grant and trespass.	Hatch act of 1887, and Adams act of 1906, experiment station.	Morrill act of 1890, supplementary endowment.	Smith Lever act of 1914, extension.	
1855			$56,320 00					$56,320 00
1856								
1857	$40,000 00							40,000 00
1858								
1859	37,500 00							37,500 00
1860								
1861	6,500 00		152 25					6,652 25
1862	10,000 00		218 97					10,218 97
1863	9,000 00		407 80					9,407 80
1864	9,000 00		726 09					9,726 09
1865	15,000 00		1,156 61					16,156 61
1866	15,000 00		1,094 27					16,094 27
1867	20,000 00		7,608 38					27,608 38
1868	20,000 00		592 49					20,592 49
1869	20,000 00	$30,000 00	17,559 00	$58 96				67,617 96
1870	20,000 00		1,320 02	2,720 93				24,040 95
1871	18,250 00	10,500 00	4,135 72	3,785 54				36,671 26
1872	18,250 00	3,000 00	217 05	7,175 65				28,642 70
1873	21,796 00	15,602 00	10 13	11,059 06				48,467 19
1874	13,000 00	15,602 00	150 13	14,061 98				42,814 11
1875	7,638 00	7,755 50	144 53	14,446 14				29,984 17
1876	7,638 00	6,755 50	1,773 09	16,830 17				32,996 76
1877	6,150 00	30,686 80	979 06	15,172 86				52,988 72
1878	6,150 00	5,686 80	826 60	15,807 09				28,470 49
1879	4,971 80	16,068 32	712 22	16,978 22				38,730 56
1880	4,971 80	7,068 32	797 55	17,837 24				30,674 91
1881	7,249 00	43,720 50	461 95	20,935 25				72,366 70
1882	7,249 00	8,945 50	358 46	22,507 45				39,060 41
1883	8,385 00	23,793 00	391 95	30,749 60				63,319 55
1884	8,385 00	10,526 00	1,259 90	27,909 72				48,080 62

1885		35,103 00	187 50	29,770 40				65,060 90
1886		22,617 00		30,461 04				53,078 04
1887		*44,040 00	198 20	†24,611 37				68,849 57
1888		30,752 50	144 20	32,406 60	$15,000 00			78,303 30
1889		*20,973 00	10 50	31,322 69	15,000 00			67,306 19
1890		*27,172 00	238 50	32,360 64	15,000 00	$15,000 00		89,771 14
1891		22,947 50	37 38	34,750 54	15,000 00	16,000 00		88,735 42
1892		22,947 50	137 38	34,948 12	15,000 00	17,000 00		90,033 00
1893		18,862 50	10 50	37,927 04	15,000 00	18,000 00		89,800 04
1894		18,862 50	433 59	44,527 26	15,000 00	19,000 00		97,823 35
1895		‡19,000 00	10 50	45,301 85	15,000 00	20,000 00		99,312 35
1896		‡16,000 00		43,886 40	15,000 00	21,000 00		95,886 40
1897		§17,700 00		43,779 54	15,000 00	22,000 00		98,479 54
1898		‖17,500 00		47,508 28	15,000 00	23,000 00		103,008 28
1899		¶8,750 00	705 00	52,526 11	15,000 00	24,000 00		100,981 11
1900		¶72,500 00	175 00	72,298 38	15,000 00	25,000 00		184,973 38
1901††		¶72,500 00		63,976 79	15,000 00	25,000 00		176,476 79
1902	100,000 00	**1,000 00		64,081 81	15,000 00	25,000 00		205,081 81
1903	100,000 00	**1,000 00		65,573 90	15,000 00	25,000 00		206,573 90
1904	100,000 00	**1,000 00	61 19	67,312 37	15,000 00	25,000 00		208,373 56
1905	100,000 00	*81,000 00		72,035 32	15,000 00	25,000 00		293,035 32
1906	157,810 00	*15,000 00		70,286 56	15,000 00	25,000 00		283,096 56
1907	173,410 00	**1,000 00		70,155 22	23,691 60	25,000 00		293,256 82
1908	173,410 00	**1,000 00		70,385 79	23,326 10	30,000 00		298,121 89
1909	173,410 00	**1,000 00		69,527 13	26,000 00	35,000 00		304,937 13
1910	173,410 00	**1,000 00		71,109 49	28,000 00	40,000 00		313,519 49
1911	173,410 00	**1,000 00		70,304 15	30,000 00	45,000 00		319,714 15
1912	228,800 00	**1,000 00		70,265 32	30,000 00	50,000 00		380,065 32
1913	228,800 00	**1,000 00		70,289 30	30,000 00	50,000 00		380,089 30
1914	228,800 00	**1,000 00		71,324 94	30,000 00	50,000 00		381,124 94
1915	308,147 25	**1,000 00		70,385 46	30,000 00	50,000 00	$10,000 00	469,532 71
1916	560,000 00	**1,000 00		71,391 56	30,000 00	50,000 00	28,032 37	740,423 93
Totals	$3,341,490 85	$832,937 74	$101,723 66	$1,984,827 23	$566,017 70	$795,000 00	$38,032 37	$7,660,029 55

*Including appropriation for weather service.
†October 1, 1886, to June 30, 1887, nine months.
‡Including $5,000 for institutes and $1,000 for weather service.
‖Including $5,500 for institutes and $1,000 for weather service.
§Including $2,750 for institutes and $500 for weather service.
††To June 30.
**Weather service.
¶Including $5,500 for institutes and $1,000 for weather service.

SUMMARY OF COLLEGE INVENTORY, JUNE 30, 1916.

College farm and park, 671 acres		$67,100 00
Athletic field and drive, 13 acres		1,300 00
Purchased C. D. Woodbury, 1916, 308.82 acres		38,602 50
Purchased in 1913, 27 acres		3,375 00
Buildings—		
Library and museum, built 1881	$22,000 00	
College Hall, built 1856	12,000 00	
Wells Hall, rebuilt 1905-06	55,000 00	
Williams Hall, built in 1869	30,000 00	
Abbot Hall, built 1888, addition in 1896	15,000 00	
Chemical Laboratory, built in 1871, south end addition 1881, east end addition 1911	35,000 00	
Veterinary laboratory, built 1885	5,000 00	
Horticultural laboratory, built 1888	7,000 00	
Entomological laboratory, built 1889, imp. 1897	7,500 00	
Botanical laboratory, built 1892, imp. 1909	20,000 00	
Armory, built 1885	6,000 00	
Greenhouse and stable, built 1873, 1879, rebuilt 1892 and 1902	6,000 00	
Boiler house and chimney, built 1893-4	3,000 00	
President's and two frame dwellings, built 1874	12,000 00	
Six brick dwellings, built 1857, 1879 and 1884	18,000 00	
One frame house, built 1885	3,500 00	
Howard Terrace dwelling, built 1888	13,000 00	
Farm house dwelling, built 1869	2,000 00	
Herdsman's dwelling, built 1867	400 00	
Horticultural barn and shed, built 1868, 1875 and 1877	1,200 00	
Bull barn, rebuilt 1905	1,500 00	
Sheep barn, rebuilt 1906	2,500 00	
Horse barn, built 1906	5,000 00	
Grade herd barn, rebuilt 1905	4,000 00	
Piggery, rebuilt 1907	1,500 00	
Dairy barn, rebuilt 1900	4,000 00	
Farm mechanics building, built 1881	1,500 00	
Poultry house, built 1906	1,000 00	
Incubator house, built 1906	500 00	
Poultry house, built 1907	1,500 00	
Three poultry houses, built 1907	300 00	
Ten brooder houses, built 1908	250 00	
Corn barn, built 1878	400 00	
Stock judging barn, built 1894	200 00	
Brick work shop, built 1857	500 00	
Observatory, built 1880	100 00	
Bath house and fittings, built 1902-3	17,000 00	
Hospital, built 1894	3,000 00	
Waiting room and book store, built 1902	1,700 00	
Three silos	600 00	
Coal shed, built 1899	700 00	
Women's building, built 1909	91,000 00	
Dairy building, built 1900	15,000 00	
Bacteriological building, built 1902	27,000 00	
Power house, built 1904	25,000 00	
Tunnel system, built 1904	45,000 00	
Coal shed, built 1905	6,500 00	
Cold storage, rebuilt 1905	2,000 00	
Amount carried forward	$532,850 00	$110,377 50

Amount brought forward	$532,850 00	$110,377 50
Buildings—Continued.		
Iron bridge over Cedar river, built 1888	1,500 00	
Bridge to athletic field	500 00	
Manure shed	600 00	
Four hospital cottages, built 1909	6,000 00	
Agricultural building, built 1909	182,000 00	
Lumber shed, built 1911	650 00	
Tile silo No. 1	500 00	
Piggery for serum production	1,000 00	
Two tenant dwellings, built 1912	2,400 00	
New dairy building, built 1913	55,000 00	
Tile silo No. 2	600 00	
Tile silo No. 3	600 00	
Veterinary laboratory, 1914	33,000 00	
Special chemical laboratory	800 00	818,000 00
Division of Agriculture—		
Department of Agricultural Education		767 31
Department of Animal Husbandry—		
Office furniture and supplies	$501 48	
Office library	843 45	
Stock	14,661 00	
Feed	1,297 15	
Miscellaneous tools and equipment	715 15	
		18,018 23
Department of Dairy Husbandry—		
Office	$2,034 98	
Chemicals and laboratory supplies	6,564 59	
Dairy barn	14,821 35	
		23,420 92
Office of the Dean of Agriculture—		
Furniture and supplies	$706 11	
Class room furniture	1,454 40	
		2,160 51
Department of Farm Crops		2,382 85
Department of Farm and Horses—		
Tool barn	$4,232 71	
Woodbury farm	654 51	
Horses	12,820 00	
Horse barn	833 20	
Office	328 79	
		18,869 21
Department of Farm Mechanics—		
Office	$867 02	
Forge shop	1,788 12	
Wood shop	1,381 65	
Machinery laboratory	1,372 98	
		5,409 77
Department of Forestry—		
Office furniture and supplies	$704 75	
Laboratory and class room equipment	3,885 65	
Books and pamphlets	700 00	
Instruments	752 05	
Tools and supplies	600 25	
Camp equipment	528 00	
Photography equipment	202 82	
Nursery stock	6,154 00	
		13,527 52
Amount carried forward		$1,012,933 82

Amount brought forward		$1,012,933 82
Department of Horticulture—		
Office	$2,007 33	
Teams and harness	1,238 50	
Class room	457 00	
Laboratory equipment	662 93	
Tools	272 35	
Greenhouse plants	898 00	
Greenhouse tools	337 60	
		5,873 71
Department of Poultry Husbandry—		
Office furniture	$227 35	
Supplies	36 47	
Books	102 63	
Tools and supplies	439 61	
Miscellaneous	4,301 82	
Live stock	2,035 30	
Feed	142 71	
		7,285 89
Department of Soils—		
Apparatus and supplies	$6,839 17	
Furniture	570 79	
Chemicals	241 24	
Extension	11 40	
		7,662 60
Division of Engineering—		
Department of Civil Engineering—		
Astronomical equipment	$772 60	
Blue printing, drawing and photography	423 21	
Drafting and computing equipment	111 94	
Furniture and office supplies	110 92	
Hydraulic laboratory	215 65	
Library	9 80	
Surveying equipment	5,333 98	
Tools	50 40	
		7,028 50
Department of Drawing and Design—		
Equipment	$231 51	
Books	10 83	
Supplies	21 20	
Tools	15 40	
		278 94
Department of Mechanical Engineering—		
Office	$642 38	
Mechanical engineering laboratory	7,532 57	
Foundry	2,613 41	
Forge shop	2,219 07	
Pattern shop	895 49	
Machine shop	10,072 14	
		23,975 06
Department of Physics and Electrical Engineering—		
Books	$5 95	
Furniture and office equipment	538 30	
Supplies	118 00	
Apparatus	10,783 01	
		11,445 26
Amount carried forward		$1,076,483 78

Amount brought forward		$1,076,483 78
Division of Extension—		
Administration	$811 88	
Upper Peninsula	171 23	
Boys' and Girls' Clubs	368 15	
Live stock	186 40	
Insect pests	45 00	
Horticulture	7 25	
Farm crops	40 50	
Home Economics	168 05	
County agents and farm management demonstration	700 01	
Markets	78 87	
Farmers' Institutes	549 90	
		3,127 24
Division of Home Economics—		
Dean's office	$374 92	
Drawing room	457 00	
Reception room	232 00	
Front corridor	245 75	
Second floor corridor	22 00	
Alcove	111 25	
Central corridor	129 85	
Private parlor	138 15	
Bed room	88 68	
Guest room	89 00	
Domestic science	2,159 09	
Domestic art	1,802 80	
Music	3,452 80	
Physical culture	920 97	
Dormitory furniture	1,304 70	
Howard terrace	1,062 83	
College cottage	546 86	
Day students waiting rooms and corridor	55 00	
Recitation room	41 45	
Linen closet	1,755 33	
Store room	78 02	
Laundry	48 00	
		15,116 45
Division of Science and Letters—		
Department of Bacteriology—		
Literature	383 92	
Apparatus and supplies	14,980 17	
Office fixtures and supplies	968 14	
Chemicals	2,218 90	
		18,551 13
Department of Botany—		
Books and periodicals	$1,919 13	
Furniture	1,954 75	
Miscellaneous supplies	349 00	
Laboratory supplies	1,252 17	
Chemicals	231 59	
Apparatus	5,796 10	
Glassware	2,111 15	
Tools	65 72	
Herbarium	8,022 35	
		21,701 96
Amount carried forward		$1,134,980 56

Amount brought forward		$1,134,980 56
Department of Chemistry—		
Furniture and fixtures	$7,221 75	
Laboratory supplies	22,694 09	
Chemicals	2,126 50	
Minerals	335 84	
Apparatus	14,856 95	
Platinum	5,552 28	
Tools	75 13	
Miscellaneous	475 63	
		53,338 17
Department of English—		
Furniture	$514 75	
Books and office supplies	675 25	
Miscellaneous	128 73	
		1,318 73
Department of Entomology—		
Office Equipment and Collection	$5,301 25	
Apiary	211 24	
Apparatus and tools	2,040 72	
Books	251 71	
Supplies	265 18	
Glassware	176 60	
Chemicals	58 71	
Sundry	30 99	
		8,336 40
Department of History and Economics—		
Economics	$206 50	
Political science and history	280 25	
		486 75
Department of Mathematics		649 70
Department of Military Science and Tactics—		
Furniture and supplies	$1,986 90	
Band properties	3,108 50	
		5,095 40
Department of Physical Culture and Athletics		262 45
Department of Zoology and Physiology—		
Apparatus and supplies	$10,582 45	
General museum	19,970 00	
Books	632 50	
		31,184 95
Division of Veterinary Medicine—		
General equipment	$915 18	
Department of medicine	240 57	
Surgery and obstetrics	3,875 73	
Department of anatomy	10,419 16	
Department of animal pathology	7,363 95	
Department of pharmacology	1,735 12	
		24,549 71
Miscellaneous—		
Carpenter shop		3,444 48
Cleaning		417 50
Dean of Summer Session		129 50
Amount carried forward		$1,264,194 30

Amount brought forward		$1,264,194 30
Hospitals—		
General hospital	$319 17	
Cottage hospitals	929 88	
		1,249 05
Library		74,245 71
Meteorological department		355 95
Michigan Weather Service		979 00
Department of Nursery and Orchard Inspection		209 25
Paint shop		1,543 84
Postoffice		1,133 45
President's office		857 63
Registrar's Department—		
Registrar's office	$359 31	
Alumni office	190 22	
		549 53
Secretary's office—		
Furniture and equipment	$1,431 41	
Supplies	865 20	
		2,296 61
Sundry		3,315 32
Wells Hall		2,476 26
Department of Water, Heat and Light—		
Fire department	$2,592 55	
Generating plant	6,029 00	
Tools	1,756 29	
Miscellaneous supplies	442 82	
Plumbing and heating stock	2,042 34	
Telephone stock	2,007 73	
Steam heating plant	14,235 30	
Electric light stock	1,643 94	
H. R. Tools	73 31	
Office furniture and fixtures	107 54	
Bath house plant	142 20	
Waterworks plant	14,463 00	
		45,536 02
Total		$1,398,941 92

SUMMARY OF EXPERIMENT STATION INVENTORY.

Lands—		
160 acres at Chatham	$8,000 00	
140 acres at Chatham, seeded and fenced	4,200 00	
480 acres at Chatham, raw and cut over lands	4,800 00	
80 acres at Grayling, fenced and improved	1,000 00	
5 acres at South Haven, fenced and improved	1,000 00	
		$19,000 00
Buildings—		
Farm residence at Chatham	$5,000 00	
Tenant house at Chatham	1,500 00	
Barn, at Chatham	3,000 00	
Root cellar at Chatham	1,000 00	
Hog house at Chatham	750 00	
Ice house at Chatham	500 00	
Chicken house at Chatham	250 00	
Old barn at Chatham	250 00	
Granary at Chatham	200 00	
Sheep barn at Chatham	1,200 00	
Piggery at Chatham	500 00	
Bacteriological stable	3,700 00	
House	1,000 00	
Station terrace building	3,000 00	
Seed room	500 00	
Slaughter house	625 00	
Storage barn	600 00	
Insectary	1,000 00	
Soil house	1,000 00	
		25,575 00
Division of Experiment Station—		
Division of Bacteriology—		
Literature	$650 80	
Apparatus	11,394 68	
Office fixtures and supplies	235 41	
Chemicals	690 48	
		12,971 37
Division of Botany—		
Chemicals	$592 23	
Glassware	1,048 87	
Scientific apparatus	3,629 35	
Laboratory supplies	401 09	
Books	130 78	
Office, herbarium and garden supplies	1,371 28	
		7,173 60
Bulletin Room		2,538 32
Division of Chemistry—		
Chemicals	$860 51	
Glassware	2,568 48	
Porcelain ware	263 08	
Miscellaneous	6,296 51	
Office furniture and supplies	820 98	
		10,809 56
Director's office		543 03
Amount carried forward		$78,610 88

Amount brought forward		$78,610 88
Division of Entomology—		
Office	$882 49	
Furniture	568 31	
Apparatus	2,029 68	
Books	1,258 19	
Glassware	329 05	
Chemicals	205 50	
Chemical supplies	29 01	
Supplies	47 00	
Stains	17 82	
Tools and machinery	100 56	
Sundry	106 06	
		5,573 67
Division of Farm Crops		2,475 90
Division of Horticulture—		
Office	$409 75	
Tools	1,658 55	
		2,068 30
Library		8,163 85
Division of Soils—		
Apparatus and supplies	$1,944 13	
Chemicals	10 34	
		1,954 47
South Haven Experiment Station		290 84
Upper Peninsula Experiment Station—		
Tools and supplies	$1,941 87	
Live stock	8,271 50	
Crops	928 00	
		11,141 37
Total		$110,279 28

REPORT OF THE PRESIDENT.

State Board of Agriculture:

Gentlemen—The close of the college year 1915-1916 leads one to consider the matter of attendance in the various courses and I present, therefore, a short summary of our attendance for the past three years, together with some data respecting the relative number of men and women students. You will note that in the past year there has been a considerable increase in the percentage of women students and that also the number of regular four year course students increased from 1435 in 1915 to 1542 in 1916. The work of the students as a whole has been of an entirely satisfactory character and I feel that the work of our students during the year just closed has been up to the standard which we all desire to see maintained at M. A. C.

ATTENDANCE STATISTICS.

1914.	
Total Attendance	2010
Regular Students (4-year course)	1521
Special Students (short course)	489
Percentage of Regular	75 3-5
1915.	
Total Attendance	1999
Regular Students (4-year course)	1435
Special Students (short course)	564
Percentage of Regular	71 3-4
1916.	
Total Attendance	1993
Regular Students (4-year course)	1542
Special Students (short course)	451
Percentge of Regular	77 1-5

COMPARISON IN ATTENDANCE—MEN AND WOMEN.

1912—Men	1438
Women	264
Percentage of Female	15 1-2
1913—Men	1371
Women	272
Percentage of Female	16 1-2
1914—Men	1666
Women	344
Percentage of Female	16 3-5

1915—Men	1665
Women	334
Percentage of Female	16 7-10
1916—Men	1610
Women	383
Percentage of Female	19 1-5

Sunday morning, March 5th, fire destroyed the Engineering Building and Shops besides doing some considerable damage to the east end of Wells Hall. With the help of students, teachers, and friends from East Lansing much valuable machinery and instruments were saved from the basement of the west end of the Engineering Building and quite a large portion of the machinery in the shops was removed without damage. The loss incurred by the fire is shown in the report of Dean Bissell.

On the afternoon following the fire I made a personal appeal by wire to Mr. Ransom E. Olds of the Reo Motor Car Co., in behalf of the college. Under date of April 29th I received the following letter from Mr. Olds:

April 29th, 1916.

Pres. Frank S. Kedzie,
Michigan Agricultural College,
East Lansing, Michigan.

Dear Mr. Kedzie—Confirming our conversation of last Saturday and my statement that I would give One Hundred Thousand Dollars ($100,000) towards the re-construction of the Engineering Building at the Michigan Agricultural College. It is my desire that you advise the Board of my action, and further advise them that in the near future I will deposit this amount in the Capital National Bank, of this city, subject to the call of the proper officials as the work progresses.

I have great faith in the Michigan Agricultural College and see no reason why it should not become one of the foremost colleges in the United States.

Very truly yours,
R. E. OLDS.

In accepting this gift on the part of the board Mr. I. R. Waterbury offered the following resolutions which were unanimously adopted:

Resolved, That the State Board of Agriculture accepts the gift of Mr. Ransom E. Olds with the deepest sense of appreciation and gratitude. In a material way the generosity of Mr. Olds relieves a situation most embarrassing and difficult. It provides means for the speedy restoration of our lost buildings and equipment; it removes the shadow of a year of grinding necessity, toward which we have been looking and of which M. A. C. has experienced many in the past. But this first great gift does much more than this, it places the stamp of highest approval upon the engineering work that has been done at this institution and forever closes the door of controversy. And this is not all, for it establishes the fact that Michigan Agricultural College, as a state and national institution, is not beyond the pale of private bequest, and that an appreciative citizen may here find a means of perpetuating his name far more lasting and gratifying than can be done with monumental stone or brazen tablet. To have one's name forever fresh in the hearts of the best youth of the land, to have given aid to struggling and worthy ambition, to have made possible a broader and better life for some of our fellows or those who may come after us, is a consummation that may add luster to the life and memory of any man.

BUILDINGS UNDER CONSTRUCTION.

A contract for the new gymnasium was awarded to Charles Hoertz & Son of Grand Rapids, Mich.

The contract for the re-erection of the Engineering Building was awarded to Fred Trier of Saginaw, the new shops to Byers Bros. Construction Co., of Kalamazoo.

A THREATENED EPIDEMIC.

The loss by the fire had hardly been discounted by the college community when on March 14th scarlet fever made its appearance among the students. The general hospital and four detention hospitals were made use of, and in addition the old boiler house was fitted up and used for detaining those suspected, or for those who had been exposed to the disease.

Those who were afflicted were given the choice of a physician, but the general health situation was in the hands of Dr. O. H. Bruegel, City Health officer of East Lansing, and Dr. Ward Giltner of the College. The State Board of Health by one of its members, Dr. Harry S. Bartholomew, advised us in taking preventive measures.

At a mass meeting the students were told of the situation before leaving for the spring vacation and urged to note any symptoms of the disease and report to their home physician. Upon their return letters were written to students requesting that they report to Dr. Bruegel should any suspicious symptoms be noticed.

The College and East Lansing milk supply was thoroughly investigated but the trouble could not be traced to this source. A map of the infested district was made, and the houses in which the trouble had appeared plainly indicated.

Total number of cases investigated and detained....	21
Total number finally diagnosed as scarlet fever......	13

It is a source of great satisfaction to know that none of the cases of this dangerous disease resulted fatally and that so far as is now known all of the students are making a complete recovery.

RESIGNATIONS DURING THE YEAR.

Prof. V. T. Wilson, Department of Drawing and Design, resigned early in the year, his resignation being formally accepted by the State Board on November 17, 1915, same to take effect September 1, 1916. Prof. R. K. Steward, Associate Professor and Acting Head of the Department of Drawing and Design at the University of Illinois, was tendered and has accepted the position thus made vacant.

In April Prof. John F. Macklin, Professor of Physical Culture and Director of Athletics since the fall of 1910, resigned to take up a business life. During Prof. Macklin's connection with the College the athletics of the institution have been of a very high order, winning teams in practically every department having been produced. The Board directed the President to tender to Mr. Macklin appreciation for the excellent services rendered during the past six years.

STUDENT EMPLOYMENT BUREAU.

As a means for assisting our students to pay their way while in attendance at college the board last year authorized the establishment of the Student Employment Bureau which was opened September 1, 1915, in charge of Mr. Don C. Heffley, who is also the general secretary of our Y. M. C. A. The results of this first year's work may be summarized as follows:

1178 Jobs reported to the Bureau.
225 Students furnished with work.
130 Employers, including college division employers, Lansing and East Lansing citizens and farmers living near by, have made use of the Bureau.

The net result to the advantage of our students cannot be shown by the above figures as it has made students acquainted with places where work may be found which usually leads to further employment.

HISTORICAL SKETCH.

In December, 1915, Dr. Beal's History of the College was received from the press and placed on sale. The publication of this work was authorized by the Board some two years ago. Dr. Beal has spent a great deal of time and effort in the compilation of this history and the various steps in the growth of the institution are all noted in an interesting and characteristic personal manner.

LIBERAL ARTS LECTURES.

Following is a list of the lectures delivered before the student body in the Liberal Arts Course during the year:

Oct. 19—J. S. Knox, Cleveland, "Business Efficiency."
Dec. 7—W. A. Blonch, Chicago, "Efficiency of Steam Boilers."
Jan. 25—Maud Ballington Booth, New York, "Out of the Shadows."
Feb. 1—John A. Lomax, Texas, "Songs of the Cowboy."
Feb. 8—Capt. Granville Fortesque, New York, "The Dardenelles."
Mar. 3—Thomas N. Carver, Washington, "Economics of Farming."
April 14—College Glee Club.
April 18—Seumas MacManus, New York, "Merry Rambles thru Ireland."

DURING THE CURRENT YEAR.

Prof. H. J. Eustace, head of the Horticultural department, was given a leave of absence from September 1st, 1915. His time has been spent in a first hand study of American horticulture in the most important horticultural regions. Special attention was given to the economic side of horticultural production and marketing. The work was done in co-operation with the United States Department of Agriculture.

The opportunities he enjoyed in making this study will be of value to the College, the Department of Horticulture and the horticultural interests of the State.

It has been my desire for some time that the experiment be tried of holding Commencement during the last week of the spring term and previous to final examinations thus permitting the student body to attend the commencement exercises and also tending to the building up of a better acquaintance between the alumni and the students in attendance. This plan was carried out this year, the date for the Commencement being June 14. The program for the week opened with an oratorio concert on Tuesday afternoon followed in the evening by the usual Cap Night fantastic proceedings, bonfire, speeches, which are all a part of our Commencement Week functions and in which the Alumni took part. So far as I am able to learn this plan is entirely feasible and meets with the approval of the college community as well as the alumni and old students. The Baccalaureate sermon was delivered on Sunday, June 11, at 3:00 p. m., by Rev. George L. Cady of the Plymouth Congregational Church, Lansing. His subject was "Work and Life." The Commencement address was delivered by Dr. W. O. Thompson, President of Ohio State University, on Wednesday, June 14th, at 10:00 o'clock a. m., on the subject "Current American Ideals."

The graduating class numbered 264, and was divided as follows:

Agriculture	104
Engineering	66
Forestry	11
Home Economics	62
Veterinary Medicine	6
Advanced Degrees Conferred:	
Master of Science	7
Professional Degrees	7
Honorary Degrees	1

On assuming the duties of the College executive, I did not feel inclined to relinquish all work as a teacher. I have therefore retained a connection with the Chemical department and have taught a class each term during the year and hope to so continue if my official responsibilities permit.

I desire here to gratefully acknowledge the hearty support of my colleagues.

Respectfully submitted,
FRANK S. KEDZIE.

REPORT OF DEAN OF AGRICULTURE.

To President F. S. Kedzie:

Detailed reports of the various departments of the Agricultural Division have been given by those in charge. No changes took place during the year in the personnel of the department staffs except by the appointment of additional instructors where needed because of the constantly increasing numbers of students. The efficiency of the instruction work was greatly strengthened during the year. Since the destruction of the Engineering Division's buildings by fire in March the Agricultural Building has been furnishing space and facilities, as far as possible, for the continuance of their work. We are glad our facilities can be used in aiding in the continuation of the work of the Engineering Division until adequate buildings and facilities are again provided.

This year's graduating class receiving the B. S. degree numbered 115, one more than last year. Specialization within the class resulted in the following division, viz.: Graduates in general agriculture 69, horticulture 35, and forestry 11, (Three of these degrees were granted at the close of the summer school). Advanced degrees were awarded as follows, viz: Master of Science 9, and Master of Forestry, 2.

The following statement gives the enrollment in the four year courses in Agriculture and Forestry for the year, viz:

Graduate Students	20
Seniors	124
Juniors	152
Sophomores	222
Freshman	248
Specials	15
Summer Session	98
Total	879

SHORT COURSE ENROLLMENT.

Two-year, 16 weeks' course, 1st year	116
Two-year, 16 weeks' course, 2nd year	54
General Agriculture 8 weeks,	
First year	103
Second year	32
Horticulture	21
Cheese making	3
Creamery	39
Poultry	4
Total	372

The total enrollment for the Agricultural Division, including both regular and short course students, amounted to 1251. The unfavorable seasonal, crop, and labor conditions of the summer of 1915 undoubtedly affected the enrollment somewhat.

My work personally was confined to meeting the following classes, viz: During the fall term the subject of Farm Management was presented to the second year short course students, Agricultural Development for freshmen winter term, and Farm Management for juniors spring term.

During the year numerous meetings of the committee on graduate study were held to pass upon the qualifications of applicants. And in addition to this much time was spent in considering the revision and new regulations governing graduate study. The Secretary of this committee, Dr. G. D. Shafer, has conducted the work of his office in a very painstaking and satisfactory manner.

The Agricultural Division faculty met frequently as necessity required to discuss various matters relating to the course, including proposed changes, schedules, etc. It is the plan to have meetings of this body at more regular intervals during the coming year for the purpose of getting in closer touch with the work of the individual departments.

The responsibilities of the Farm Superintendent, Mr. R. S. Hudson have been increasing rapidly, largely owing to improvements in fencing, and being involved in connection with the purchase of the Woodbury farm, on which extensive improvements, including building repairs, have been made during the year. The demands on this department for team work and sundry services are rapidly increasing.

There is an ever increasing demand for the extension of our short courses to two years of six months each. It is earnestly hoped that provision for such a change may be made during the coming year.

I greatly appreciate the generous support of the Agricultural Division Staff, the President of the College, and the State Board of Agriculture.

Respectfully submitted,

R. S. SHAW,
Dean of Agriculture.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF HORTICULTURE AND LANDSCAPE GARDENING.

To the President:

Sir—I herewith submit the following report of the Department of Horticulture and Landscape Gardening for the year ending June 30th, 1916.

Professor H. J. Eustace, head of the department, was granted a year's leave of absence beginning September first, 1915. His absence necessitated the engagement of an additional instructor to help in the teaching work. Mr. George T. Hayes was engaged the latter part of September and remained with the department during the fall and winter terms.

During the spring term the teaching work was carried on by Mr. Loree and the writer.

In addition to Mr. Hayes' services, we employed Mr. Floyd Barden to help in teaching the short course classes.

Instruction work given during the year to the regular college classes is here briefly summarized:

FALL TERM.

Class.	Subject.	Number enrolled.
Soph. Ag	Hort. 2	224
Junior Ag	Hort. 4	38
Senior Ag	Hort. 7	35
Senior Ag	Hort. 10a	35
Senior Ag	Hort. 11a	32
Senior Ag	Hort. 12a	4
Junior and Senior Women	Hort. 14	42

WINTER TERM.

Class.	Subject.	Number enrolled.
Soph. Ag	Hort. 3	193
Junior Ag	Hort. 5	43
Senior Ag	Hort. 8	35
Senior Ag	Hort. 10b	35
Senior Ag	Hort. 11b	32
Senior Ag	Hort. 12b	4

SPRING TERM.

Class.	Subject.	Number enrolled.
Junior Ag	Hort. 6	43
Senior Ag	Hort. 9	35
Senior Ag	Hort. 10c	35
Senior Ag	Hort. 11c	32
Senior Ag	Hort. 12c	4
Junior and Senior Women	Hort. 13	32

In addition to these courses instruction was given, in the winter term, to short course classes as follows:

Fruit Growing, lecture and laboratory work, fifteen hours per week for eight weeks.

General Agricultural Short Course, lectures, five hours per week. (Four sections for eight weeks.)

Two Year Short Course, one section for eight weeks.

Short Course in Home Economics, three hours per week for six weeks.

Lack of room and of proper facilities for teaching large classes in this building necessitates the use of class rooms and laboratories in other buildings. Our laboratories do not afford sufficient room for the present size of our divisions either for the upper classes or the sophomore work.

During the past winter, our laboratory work in Hort. 3 was handled in the greenhouse for the first time and we take pleasure in reporting the success of this departure from the previous schedule. It is to be hoped that in the near future, with additional greenhouse equipment we will be able to handle more of our laboratory work along the lines of plant propagation and general horticulture in the greenhouse.

During the past year, the work of caring for the campus has been considerably increased. This has been due largely to the active expansion and development that is being carried on, and to the increased number of buildings and of people occupying and using the campus grounds. With the improvement of the road connecting Lansing and East Lansing, the campus drives will be used by a larger number of vehicles than ever before and it is hoped that money will be available to properly construct and maintain these drives. Additional plantings and landscape improvements are also desirable in many spots on the campus and these we hope to take care of in the near future.

It is a pleasure to report the loyalty and support that every member of the department has rendered during the year and that the work of Instructors Thomas Gunson, R. E. Loree and George T. Hayes; Field Representatives C. W. Waid and J. H. Carmody; Assistant Horticulturists W. C. Dutton and H. J. Bock; and Miss Nellie Strudley, Stenographer, has been very satisfactory.

Respectfully submitted,

C. P. HALLIGAN,
Acting Professor of Horticulture.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF DAIRY HUSBANDRY.

To President F. S. Kedzie:

In reviewing the college year just closed we are pleased to report that the entire department has been kept unusually busy, and, if we may be permitted to pass upon accomplishments at so close a range, the results seem reasonably effective.

During the year instruction in the care, feeding, selecting, breeding, and management of dairy cattle has been given to all agricultural freshmen and juniors, as well as to all those taking the short courses in general agriculture. All sophomores and eighty-four of the short course men, have had instruction in the testing of dairy products, and the operation and care of the cream separator.

Forty-two of the one hundred thirteen agricultural seniors took one or more senior options in dairying, and eighteen of these took their major in dairy manufactures.

Thirty-nine men registered for the winter course in creamery butter making, and three for cheese making.

During the week of December 18-23, 1915, a Conference for creamery owners and managers, and a Short School for experienced butter makers, was held at the college dairy. This was attended by nearly forty people, thirty being butter makers or creamery inspectors. Besides the regularly employed instructors of the department, Professor Bouska of Chicago, Ill., was secured for the week and gave valuable assistance. The eight weeks' course in butter making is too long and too elementary to properly provide for the busy creamery man of experience. It is therefore planned to make this Conference and Six-day School a permanent annual feature.

During the summer of 1915 the dairy barn was remodelled, and the stable underwent much needed rearrangement and repair. The large wooden silo which stood in the way of the extension of the stable was removed, and two vitrified tile block silos were constructed at the west end of the front portion of the barn. A new cement-block house for weighing, straining and cooling the milk is among the improvements.

Early in January of the present year a full equipment of milking machines was installed in the barn and the entire dairy herd has since been satisfactorily milked by the use of machinery.

In the fall of 1914 the responsibility for purchasing the milk supplies for the Student Boarding Clubs, and of properly pasteurizing the same, was placed upon the Dairy department. A new milk route was established, and the former route reorganized and extended. During the past two years the production of milk along these routes has been increased, and we have for the first time had sufficient supplies of raw material to properly care for the laboratory exercises in the several courses in dairy manufactures, and provide the degree of elasticity so necessary in the milk supplies for the Boarding Clubs.

Two new men were added to the department force at the beginning of the college year. Mr. J. E. Burnett assumed the care of the details pertaining to the verification of all Advanced Registration records. Mr. A. C. Lytle has been assisting Mr. F. T. Riddell in the field investigations regarding the cost of milk production. Since March 1, 1916, Mr. Lytle has been stationed at Webberville, and Mr. Riddell at Howell.

Throughout the entire year in all that has been attempted we have been most faithfully and ably assisted by the entire corps of instructors, and credit to them our full measure of appreciation for service and loyalty. The list of the instructors is: C. E. Newlander, H. E. Dennison, F. T. Riddell, W. D. Meltzer, F. W. Small, Alison Ransford, J. E. Burnett and A. C. Lytle.

For continued and deserving service Mr. Newlander and Mr. Dennison have been raised to the rank of Assistant Professor.

We are sorry to lose the faithful services of Mr. Small who has for the past two years had charge of the work in market milk.

Respectfully submitted,
A. C. ANDERSON,
Professor of Dairy Husbandry.

East Lansing, Michigan, June 30, 1916.

REPORT OF THE DEPARTMENT OF FARM CROPS.

President F. S. Kedzie:

Dear Sir—The following is a brief report of the Department of Farm Crops for the fiscal year ending June 30, 1916:

The courses of study offered by this department and the number of students in each are given below:

Farm Crops I	291
Farm Crops II	215
Farm Crops III	53
Farm Crops IV	54
Farm Crops V	44
Farm Crops IV, Summer Session	6
First year, two-year course	99
Second year, two-year course	67
First year, eight-weeks course	106
Second year, eight-weeks course	16
Graduate Students	2
Total	953

Mr. Joseph F. Cox has had charge of the freshman and sophomore classes and the second-year class of the two-year course, and has assisted in Farm Crops III and IV.

Mr. Frank A. Spragg has had charge of Farm Crops V, and I have had charge of Farm Crops III and IV, the first-year class of the eight-weeks' course and one section of the first-year class of the two-year course.

Mr. A. L. Bibbins, who was appointed as instructor in Farm Crops September 1, 1915, has had charge of the second-year class of the eight-weeks' course and one section of the first year class of the two-year course and has assisted with several of the other courses.

Mr. E. E. Cushman, Mr. M. R. Freeman, Mr. G. I. Hobbs, Mr. B. W. Householder, Mr. L. R. Luther, Mr. E. B. More and Mr. H. M. VanAken have acted as student laboratory assistants in the various courses offered by the department.

I wish to express my appreciation of the hearty co-operation received from all of the members of the department, and also from the the student assistants, which has made it possible to efficiently handle the work.

The instruction work of the department is now well systematized, printed laboratory sheets being provided which encourage individual study on the part of the student and help to give a comprehensive understanding of the more important factors of crop production. The greatest need is more instructional plats, crop samples, exhibits, charts, and other illustrative material. Additional material of this character will have to be provided largely by extending our plat experiments and by collections and exhibits prepared by members of the department.

Respectfully submitted,

V. M. SHOESMITH,
Professor of Farm Crops.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF SOILS.

Pres, F. S. Kedzie, Michigan Agricultural College:

Dear Sir—I take pleasure in furnishing you with the report of the Soils department for the fiscal year ending June 30th, 1916.

It is indeed gratifying to be able to report that the various lines of work undertaken by the members of the department are progressing satisfactorily.

With respect to the various courses it is doubtless true that the work offered this past year was more logically presented, and of a higher grade, and that the discipline was better than formerly, due to additional and efficient assistants, more equipment, and to a greater knowledge of the attitude and training of the students that we have dealt with. The introductory courses, especially, were much better disciplined, owing to the important fact that the previous custom of dealing with students in large sections was abandoned, a number of smaller ones being substituted. We are forced to conclude that the plan adopted is essential for maximum efficiency in educational work. The senior electives should be made somewhat stronger during the next and following years as our knowledge of the soils of the State increases, and the students who come to us are somewhat more thoroughly grounded in the sciences. It is unquestionably true that we could present, in some instances, more advanced work if the men as a whole were better trained in chemistry and physics. In this connection it is exceedingly gratifying to us to learn that the enrollment in the courses that we have suggested as electives has increased greatly. We are highly in favor of a thorough training of the students in the sciences spoken of above.

During the year four graduate students were enrolled for major work in this department, two of whom received their degree of Master of Science. We are greatly in favor of graduate work—of a very high grade—being offered by the College. The presence of graduate students adds much dignity to any department, and certainly has a splendid effect upon the undergraduate students and members of the staff as well.

We were able to reach a number of short course men during the winter and certainly consider this one of our best and most important educational features. The work is always well received by these men. It is well to note that this phase is to be reorganized and made more efficient, although the quality in the past has been high.

The enrollment in the various courses during the year is as follows:

Soils 2a	190
Soils 2b	194
Soils 4a	28
Soils 4b	40
Soils 4c	45
Short Courses	249
Graduate	4

With respect to the extension activities in the past there is not a great deal to say, inasmuch as the department has not had funds for this purpose at its disposal. Probably it is well that such has been the case, inasmuch as all of our time and energy have been taken up by other matters. We have considered that an efficient organization locally is of prime importance but following this more attention could well be given to outside activities. With the increase of the Smith-Lever funds and additional knowledge of the soils of the State, we are firmly convinced that the field work should be strongly supported. Never was there more discussion of the various soil management problems, such as the use of lime, green manures, fertilizers, etc., and, indeed, greater need for vigorous, educational campaigns along these lines than at present. We are forced to so conclude, when we note in the last year's report of the State Leader of the Extension Division that the County Agents place various soil problems in the foreground and when we take cognizance of a large number of requests for such information by farmers. Indeed, the lack of definite information concerning these lines is almost unbelievable. Certainly this department of the College should be represented by highly trained men in the One Week Schools that are to become such effective means of dissemination of scientific knowledge of agriculture. These representatives should be provided with well outlined extension courses dealing with soils and fertilizers and, unquestionably, should be responsible to the department that has charge of and is carrying on fertility work in different parts of the State, being thus enabled to obtain first hand information with respect to the results obtained and their interpretation.

The writer wishes to express his appreciation of your timely advice and suggestions, as well as of the loyalty and hearty cooperation of the various members of the department.

Respectfully yours,
M. M. McCOOL,
Professor of Soils.

East Lansing, Mich., June 30, 1916.

REPORT OF DEPARTMENT OF ANIMAL HUSBANDRY.

President F. S. Kedzie:

Dear Sir—I have the honor to submit the following report of the Department of Animal Husbandry for the year ending June 30, 1916.

Schedule of class work given by department staff during the year:

Class.	Subject.	Section.	Teacher.	Hours per week.	Students enrolled.
Freshman	Animal Husbandry 1	1–3	Mr. Edwards Mr. Clark	6	72
Freshman	Animal Husbandry 1	4–6	Mr. Edwards Mr. Clark	6	75
Freshman	Animal Husbandry 1	7–9	Mr. Clark Mr. Edwards	6	54
Freshman	Animal Husbandry 1	10–12	Mr. Clark Mr. Edwards	6	63
Junior	Animal Husbandry 2		Prof. Brown	6	117
Senior	Animal Husbandry 5		Prof. Brown Mr. Clark	15	(one half term) 28
Two year Short Course (1st term 2nd year 16 weeks)	Study of Types		Mr. Edwards Mr. Clark	10	106
Two year Short Course (1st term 2nd year 16 weeks)	Stock Feeding		Prof. Brown	5	114

WINTER TERM.

Class.	Subject.	Section.	Teacher.	Hours per week.	Students enrolled.
Junior	Animal Husbandry 4		Prof. Brown	5	95
Senior	Animal Husbandry 6		Prof. Brown	6	21
Senior	Animal Husbandry 6		Prof. Brown	6	18
Two year Short Course (16 weeks)	Study of Breeds		Mr. Edwards Mr. Clark	10	96
Two Yr. Short Course (2d Yr. 16 Wks)	Stock Judging		Mr. Clark	6	48
Two Yr. Short Course (2d Yr. 8 Wks.)	Stock Judging		Mr. Edwards	6	52
Two Yr. Short Course (1st Yr. 8 Wks.)	Types and Breeds		Mr. Edwards	6	101
Two Yr. Short Course (1st Yr. 8 Wks.)	Animal Feeding		Mr. Clark	5	65
Two Yr. Short Course (1st Yr. 8 Wks.)	Animal Feeding		Mr. Edwards	5	44

The addition of Mr. W. N. Clark, a graduate of the University of Wisconsin, to the staff, September 1st, 1915, made possible a division of a few of the larger sections and resulted in more efficient instruction. Maximum efficiency however, cannot be attained until the staff has been increased to a point where sections can be reduced to 30 students each. While ample in size when built, the judging pavilion is now taxed to its utmost capacity. A much larger pavilion with a greater number of compartments will be a necessity in the near future.

Aside from their teaching duties which are very heavy during the fall and winter terms, the members of the staff devote a considerable portion of their time to the management of the herds and flocks.

Mr. W. E. J. Edwards has been in direct charge of the swine. At present he has under way two experiments, both of which require close personal attention. One has for its object the determination of the most efficient method of utilizing alfalfa fields for pasture without materially injuring the stand of alfalfa. A second experiment is being carried on to determine the advisability of the self-feeder for growing pigs.

Mr. Clark assists the writer in the management of the sheep and beef cattle. During the past winter 24 steers were on experimental rations to determine the value of cull beans as a protein supplement to corn and corn silage.

With the sheep flock an effort is being made to determine the most economical winter ration for breeding ewes; while during the grazing months the ewes and their lambs are being pastured entirely on sowed crops to determine the economy of sowed crops, the acreage required to graze a given number of sheep and the efficiency of the above method of pasturing as a means of avoiding infestation with internal parasites.

The cattle herds have been increased during the last year by the purchase of an Aberdeen Angus sire from the Woodcote Stock Farm, Ionia; a Hereford sire from Mr. J. H. Bereman, Aurora, Illinois; and a Shorthorn sire from Mr. A. E. Stevenson, Port Huron.

Every possible effort is being made to bring the individual members of the herds and flocks up to a high standard of individual excellence. In the past we have been somewhat handicapped from not having funds to purchase as high-class sires as seemed desirable. Nevertheless, some progress has been made but if it is to be continued a higher class of sires must be purchased in the future. This will necessitate the expenditure of considerable more money than has been the case in the past.

Respectfully submitted,
GEO. A. BROWN,
Associate Professor of Animal Husbandry.

East Lansing, Mich., June 30, 1916.

REPORT OF DEPARTMENT OF POULTRY HUSBANDRY.

President F. S. Kedzie:

Dear Sir—I have the honor to present the following report for the Department of Poultry Husbandry for the fiscal year ending June 30, 1916.

Our buildings have been placed in good repair. Our stock is in healthy condition. Our grounds have been increased from 2.45 acres to 10.65 acres.

BUILDINGS.

We are occupying fourteen buildings made up as follows: two large laying houses, three colony laying houses, seven colony houses for growing chicks, one incubator house and one feed house.

EQUIPMENT.

The department has operated six incubators,—three 150-egg size, two 200-egg size, and one 1,200-egg size. Instructions have been given students upon the running of lamp, electric and coal heating systems as applied to incubation. Ample facilities have been provided for brooding 3,000 chicks.

Our present stock consists of the following breeds,—Barred Rocks, Buff Rocks, Partridge Rocks, White Rocks, White Leghorns, Brown Leghorns, Buff Leghorns, Black Minorcas, White Wyandottes, Rhode Island Reds, Silver Spangled Hamburgs, Light Brahmas, Black Langshans, Cornish Indian Games, Black Hamburgs, English Pit Games, Buff Wyandottes and Buff Orpingtons. Large flocks of fowls most popular with farmers are maintained, the others are simply for demonstration and investigation purposes for students. Besides the above we have a small flock of ducks and turkeys.

Table showing the kind of fowls and age.

Hens	780
Cockbirds	42
Young stock (4 mo. old)	149
Young stock (2 mos. old)	1234
Young stock (1 mo. old)	616
Young stock (15 da. old)	215
Turkeys (old)	3
Turkeys (young)	15
Ducks (old)	3
Ducks (young)	4
Total	3061

The instruction work during the year has been as follows:

Summer Term:—Six men and two women enrolled. Lectures were given daily for the six weeks. During the term, fifteen visitors were present with the class.

Fall Term—Nine men enrolled in Poultry Husbandry 2. The students were required to build a colony house best suited for the farmer or the back door yard in the city. Special work was given in fattening, killing and marketing. The results tabulated by students showed an average profit of 31% on the money invested. The work was made as practical as possible.

Winter Term—Thirteen men enrolled. Practical work was given in poultry feeding and judging, not only for the fancy but for utility purposes as well.

A short course, covering eight weeks, was given to a class of five men and four women. Lectures were given daily. Work with incubators and brooders was required of each student.

Spring Term—Eleven men enrolled for Poultry Husbandry 4. The class was divided into five sections and each section was given a poultry project along investigational lines with the idea of teaching them how to conduct a poultry experiment.

One hundred fourteen men and one woman enrolled for Poultry Husbandry 1. Lectures were given twice each week along practical lines.

THE WORK.

Fruit was grown in the different runs. Corn and cabbage were grown upon the grounds that had been occupied by the fowls. This was done to sweeten the soil and take from it such infection as plant life can counteract if given a chance.

An experiment with electric lighting of the laying house was conducted through the months of November, December, January, February and March. The experiment was not carried on for the purpose of increasing egg yield but to increase the vigor of the flock. As a result of the experiment higher fertility, greater hatchibility and we believe, an increased livibility has been obtained.

Many projects have been started for next year, including some involving the principles of breeding, feeding and general environment of fowls.

RESULTS.

During the year the flock of fowls has been increased from 140 head to 3,061 head.

Trap nest records have been kept from every hen on the plant.

The work of pedigreeing the chicks from two hundred sixty-five hens has been begun.

More than forty dollars worth of plums were harvested, eighty-seven bushels of corn were husked and over 2,000 heads of cabbage were placed in the cellar for feed during the year.

Six thousand six hundred eggs for hatching purposes have been distributed to breeders and farmers throughout the State. An open front laying house for 100 hens is under construction by summer school students.

A bulletin designed for use in poultry club work has been issued. Bulletins on poultry house construction, incubation and breeding are in preparation.

Respectfully submitted,
C. H. BURGESS,
Associate Professor of Poultry Husbandry.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF FARM MECHANICS.

President F. S. Kedzie:

Dear Sir—I have the honor at this time to submit the report of the Department of Farm Mechanics for the year 1915-1916.

I desire to express my appreciation of the helpful services and cooperation of other members of this department.

Mr. A. Watt, instructor in blacksmithing, has had an increasing amount of repair work and horseshoeing in addition to his regular classes. He should be relieved of part of this work.

Mr. C. N. Rix, instructor in woodworking for agricultural students, has made great efforts to emphasize practical instruction and his work has been appreciated by the students.

Mr. O. E. Robey has completed the first full year of Extension Work in Household Engineering. He is submitting for publication results of his experience which, I trust, will be of value.

Mr. Samuel Toms has had charge of the equipment in the cement and machinery laboratories, and, in addition to keeping this equipment in order for class work, he has been called upon to assist in many other ways.

I am also indebted to Mr. Wilson Duncan, Mr. D. P. Flower, Mr. R. G. Bigelow and Mr. H. J. Gallagher, who assisted in the instructional work in the short courses.

EXTENSION.

The work of the extension representative, Mr. O. E. Robey has been confined largely to the project of water supply and sewage disposal.

I attended two one-week schools and five institutes where the gas engine and tractor, concrete construction, farm buildings, and water supply and sewage disposal were discussed. We have had calls for assistance in farm drainage. I would recommend that this subject be given more attention throughout the State. Many blue print, floor and framing plans of farm buildings have been sent out to meet individual needs.

INVESTIGATION.

Some investigational work has been done this year. Three experimental septic tanks which are giving us valuable information have been constructed near the College. Some experimental work has been done on securing a low cost automatic siphon for the septic tank. A study has been made of marl handling machinery, interest in this being stimulated by the increased use of marl and the desirability of securing excavating machinery which can be operated economically by a small group of farmers. The farm tractor has been much discussed in the last year and efforts are being made to secure records and cost data on machines now in use. Experiments have also been made with windmill electric lighting, which promise interesting results.

INSTRUCTIONAL.

Following is a summary of the total number of students receiving instruction in the various subjects: Woodwork, 420; Forge Work, 414; Power Machinery, 77; Farm Machinery, 47; Farm Structure, 68; Farm Conveniences, 23. In addition were the short courses with 87 in Farm Engineering, 50 in Building Designing, 39 in Creamery Mechanics, and 24 in the class in Gas Engines and Spraying Machinery for horticultural students. A course in Farm Conveniences was given for the first time. While meager laboratory equipment was provided for this course it was found practical and promises much as it can be developed.

Respectfully submitted,
H. H. MUSSELMAN,
Associate Professor of Farm Mechanics.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF FORESTRY.

The President, Michigan Agricultural College:

Sir—I have the honor to submit the following report for the Department of Forestry for the year ending June 30, 1916.

The work of instruction has been carried on during the year as described in the College catalog, and also two short courses in forestry were given in the winter term covering four and two weeks respectively. The course in Farm Forestry, given to the freshmen, calls for three lecture or recitation periods a week. In the past, one of these periods has been devoted to outdoor laboratory work. Owing to the size of the class and to the fact that one hour is not sufficient for laboratory work, the out door work was given up this year and the course confined to lectures and recitations. This increased the efficiency of the instruction and has resulted in a better course. The minor changes made in a few of the other courses have also worked out satisfactorily.

Eight students went on the lumbering trip during the Christmas vacation to Davis, West Virginia, where the Babcock Lumber and Boom Company gave them every assistance in examining their operations and plant. This trip was not required and was made at the request of the students themselves. The Summer School was again held on the lands of the Cummer-Diggins Company at Dayhuff Lake, near Cadillac, where the company has kindly given us the use of a good set of buildings. The students take a great deal of interest in this summer school work and it is a valuable part of the course. The Forestry Club has been active, the meetings were well attended, and many good speakers were obtained during the year.

Eleven men received the degree of B. S. in Forestry at Commencement. Graduates of the department are obtaining positions in increasing numbers with lumber companies and timber preservation concerns. Such employment of men trained in forestry promises that in the future the timber resources of the country will be conserved as they have not been in the past.

The maple syrup plant which was established last year was again operated successfully. Two hundred additional trees were tapped this year, bringing the number of buckets hung up to six hundred. Experimental work is being carried on with a view to determining the effect on yield of sap and on the trees, of hanging from two to five buckets on a tree, and an accurate record of costs of production is being kept.

Experimental planting on the jack pine plains, adjacent to the College lands in Iosco and Alcona counties, has been started in order to determine whether rapidly growing trees suitable for pulpwood, such as poplars and aspen, cannot be raised there. If practicable, such trees could be harvested for this purpose at a much younger age than would be required for saw logs and their production would furnish a profitable use for such lands. Carolina poplar cuttings have been furnished both to the State and to the Federal Forest Service to be planted experimentally on the State and National Forests on the jack pine plains. Next year I hope to try other poplars for the same purpose.

The forest nursery has been operated successfully, planting stock amounting to 120,000 trees having been sold during the year. This is less than last year owing to the fact that but little seed was put in four and five years ago, resulting in a shortage of stock this year. We have a large supply of trees which will reach salable size next year.

In accordance with the authorization given by the State Board of Agriculture, the department offered to give trees, sugar maple and white ash from 3 to 4 feet high, to the schools in the State for Arbor Day planting. One hundred and eighty-five schools took advantage of this offer and a great deal of interest was aroused in the movement for more beautiful school grounds.

Experimental work with basket willows has progressed satisfactorily. Under a cooperative agreement the department furnished cuttings for one-half acre at Spring Lake, the owner of the land to plant and manage the holt in accordance with the recommendations of the department, furnishing us with cost data. The proposed experimental holts at Ionia and Grand Rapids could not be established this year owing to the flooded condition of the land, but the experimental holt at the College was increased in size by about one acre. The department will be in a position next year to furnish cuttings for planting on a large scale.

The sand dune reclamation work has also progressed satisfactorily, a number of owners having been visited and much planting having been done under the advice of the department. It is estimated that there are 410,000 acres of sand dunes in the State, many of which are gradually shifting and nearly all of which can be made valuable by establishing forest growth. The department has evolved an effective and cheap method of permanently fixing these dunes, and this plan is now being followed in several places.

The department has also furnished assistance to towns and cities in the care and repair of their shade trees. Public demonstrations of tree repair have been given with a view to showing how such work should be done. Municipal, or city forests, are also being developed as far as practicable, the aim being to encourage towns to secure and reforest waste or cut-over lands for park purposes from which a revenue can be derived in the future by the occasional sale of timber. This work should be pushed more vigorously. Other states have taken it up with success and the time is now ripe for it in Michigan.

The department has started a current file of prices paid for saw logs, stumpage and rough lumber in different parts of the State which has been found useful in assisting farmers to dispose of the products of their woodlots. Demonstrations and advice on the care and management of woodlots have been given. The number of requests for assistance in planting and woodlot work is quite large.

Owing to the resignation of Mr. C. A. Tyler, Extension Representative in Forestry, in the winter term, all of the field work in forestry was thrown on the members of the department. Professor Sanford spent a considerable portion of the spring term in the field and a large amount of extension work has been attended to. Such work should be pushed vigorously.

Respectfully submitted,
A. K. CHITTENDEN,
Professor of Forestry.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF AGRICULTURAL EDUCATION.

To the President:

Sir—I herewith submit a brief report of the work of the Department of Agricultural Education during the year ending June 30, 1916.

1. *Teaching.* I have taught the courses in Pedagogics for both men and women. The courses given to the women are known as Pedagogy I, II and III, or Psychology, School Administration, and History of Education. There has been one section of the women, consisting of about 60 students. The courses given to the men are known as Pedagogy IV, V and VI, or Psychology, School Management and Administration, and Agricultural Pedagogy—or the Methods of Organizing Courses in Agriculture for Secondary Schools, including instruction, laboratory and field exercise, and extension service. I have had two sections of the men, about 40 in one section, and 70 in the other. This makes 15 hours of teaching.

As a part of these courses in Pedagogics we require the actual observation of the work done in the public schools. Our young women have inspected the work of the city schools of Lansing, and the work in Domestic Science and Art in various schools of the State where these subjects are taught. The men have made their observation visits to high schools where agriculture is taught. The students are required to observe the methods, school organization and administration, laboratories, laboratory equipment, and the organization of field work, and are required to make specific written reports upon their observations.

2. *High Schools.* During the year four year courses in Agriculture have been given, in whole or in part, in 48 high schools. The instructors, for the most part, are graduates of this institution. The work in agriculture as planned for the high school is organized as follows:

First year—Agricultural Botany.
Second year—Farm Crops and Horticulture.
Third year—Animal Husbandry.
Fourth year—Soils and Farm Management, which includes Farm Mechanics, Farm Machinery, and Farm Accounting.

The course in agriculture thus requires 25% of the high school student's time. About 2500 young men and women have been pursuing these agricultural courses during the year.

A number of other high schools in the State are giving some instruction along agricultural lines but they do not employ special teachers and do not have well organized courses of study.

I have visited and organized courses of Agriculture for the ensuing year in the high schools at the following places: Ypsilanti, Elk Rapids, St. Joseph, Owosso, Three Rivers, Durand, Howell, Colon, Munising, Scottville, Lawton and Belding. Thus 12 new schools have been added to our list and before the schools open in September I think several others will introduce the agricultural work.

One high school will discontinue the teaching of agriculture, and two others, where they have been employing college graduates, have employed normal school graduates to take charge of their agricultural work.

The University of Michigan accepts the high school work in agriculture for entrance credit under certain conditions, and the University authorities have appointed me to make proper reports to them upon the character of the agricultural work. The University recognition being based upon my recommendation.

In order that we may work intelligently on this basis I have arranged a minimum standard of requirements for instruction and equipment as a basis for recognition which may be given by the University and by the Agricultural College. This standard of efficiency will, of course, be adjustable.

The instruction in agriculture given in our high schools is accompanied by proper laboratory work and field and farm demonstrations in order that the high school student, while securing the theory of the best agricultural practice, may have an opportunity to demonstrate what he can do. This field work offers a very large opportunity of practical value. We are applying the general term "Home Projects" to this class of instruction. The annual reports of the teacher of agriculture show that a large percentage of the boys actually take up and work out these home projects during the summer season, and for this work school credit is given.

In my judgment, the instruction in agriculture given in the public high school constitutes a large and important feature of our general extension work, because if we are to have farmers in the next generation, we must secure their interest during the adolescent period of life.

3. *Extension Service.* I have conducted four Teachers' Institutes during the year, and have given a number of addresses before Granges, Farmers' Clubs, and Farmers' Meetings. I have also given considerable attention to the rural schools through cooperation with the County Normal Training Classes and with the County Commissioner of Schools.

4. *Publications.* During the year we have published two pamphlets —first, Bulletin No. 14, which is a Teacher's Hand Book of Agricultural Instruction in Secondary Schools. Bulletin No. 15 is a printed report concerning the work in agriculture in our high schools. This bulletin has been distributed to all the high schools in the State, and we have had a very large call for both bulletins from other states.

5. *Teachers.* The number of students electing the courses in Pedagogics and thus preparing themselves to receive the State Teacher's License has brought this institution into prominence in connection with the public schools.

We have organized a regular system of registration of teachers and use our best efforts to assist the young people in securing positions, both in the State and outside of the State. This work occupies a large amount of time and almost endless correspondence. We have assisted in securing positions for 28 young women, most of them will teach Domestic Science and Domestic Art. We have also located 24 young men; 22 of these will teach Agriculture, and two of them Manual Training. The young women receive salaries ranging from $600 to $800, and the young men receive salaries ranging from $700 to $1,000.

Thus far we have been able to supply all of the schools with trained men for the Agricultural courses, and we are supplying about 50% of the schools which teach Domestic Science. At the present time there is a surplus of teachers for both subjects. It is evident that the claim which has been frequently made, that the states are unable to supply properly trained teachers for these special subjects, can no longer be maintained in Michigan.

6. *The State Society for the Promotion of Agricultural Education.* This society was organized in 1909 and consists of the Teachers of Agriculture, Superintendents of Schools, County Commissioners, and others who are especially interested in the extension of Agricultural Education. This society meets annually at the Agricultural College. The last meeting was held on April 21st and 22nd.

In addition to discussing the means and methods of Agricultural Education, the question of an organization of the Teachers of Agriculture to cooperate with the Fruit Associations of Western Michigan in the marketing of small fruits was presented by Mr. Nash of Muskegon, and a committee was appointed to work up plans for this new venture. The committee consists of Mr. Nash of Muskegon, Mr. MacVittie of Bay City, and Mr. Servis of Monroe.

Prof. A. W. Nolan of the College of Agriculture of Illinois gave a fine address on Agricultural Education.

The following officers were elected for the ensuing year—

President—K. K. Vining.
Vice-President—F. J. Gibbs.
Secretary—T. H. Caldwell.

At the last annual meeting it was voted that we should request the authorities of the State Teachers' Association to permit the organization of an Agricultural Section of that body. This permission was given by the Executive Committee of the State Association, and at this meeting L. R. Servis of Monroe was elected Chairman of the Section, and E. J. Smith of Blissfield, Secretary.

The association discussed carefully the question of the proper field of work for the Teacher of Agriculture during the summer vacation, and decided that in order to secure the best results the Teacher of Agriculture should be employed for the entire year.

7. *The Extension Reading Course.* This has been the eighth year of the work of this course. We have enrolled in that time about 600 farmers and farmers' wives. The new enrollment for the current year has been small because it has been impossible for us to give very much personal attention to it. I feel that this is an important phase of extension

service and am very glad that it has been transferred from the Department of Education to the Department of Extension.

8. *Visitation and Supervision of Schools.* The work of introducing agriculture into the public schools of the State was assumed by the Agricultural College, and made the chief work of the Department of Agricultural Education. This implied the development of proper courses of study, consultation with Superintendents of Schools and Boards of Education, visitation of the schools after they were organized, and the making of suitable suggestions concerning increasing the efficiency of the work. All of this is a voluntary service for the public schools on our part as we have no legal supervisory authority.

I am pleased to report that in all cases we have been met courteously and cordially by those in charge of the public schools, and so far as I can observe our suggestions have been welcomed.

In assuming such a responsibility we become responsible for keeping the standard of agricultural teaching on at least as high a plane as that already maintained by years of development in other subjects. I have taken charge, personally, of the work connected with introducing the courses and advising Boards of Education with regard to the employment of teachers, and I have visited and observed the work of as many schools as possible in connection with the regular work of teaching, which I am required to do in the College. My assistant, Mr. Grover, has had charge of the larger part of the visitation and observation work, and he has become a very efficient man. We have had 48 schools directly under our supervision during the past year, and for the coming year there will be about 60.

I am pleased to report that in all cases the work has been satisfactorily performed. Some of our instructors have become so valuable that they have been taken from us and employed as County Agents, or have been called as instructors in higher institutions of learning. I think we may have considerable pride in our graduates who are maintaining such a fine standard of work and instruction.

9. *Assistant in Agricultural Education.* Mr. E. Lynn Grover, who has been the Assistant in Agricultural Education for the past year, has been untiring in his efforts to supervise and improve the school work. In addition to this he has been used by the Extension department as an instructor in Farmers' Schools for several weeks, and he has been called upon to give addresses before farmers' and teachers' organizations in many parts of the State. I submit the following brief summary of his labors, showing the range of his work and also the distance it has been necessary to travel in accomplishing these results—

Miles travelled to inspect School Gardens..........	650
Miles travelled to act as judge at School Fairs....	400
Miles travelled to talk on Agricultural Education..	600
Miles travelled to visit and inspect High Schools...	9,825
Total mileage	11,475

Mr. Grover is an efficient speaker and has been particularly successful in his work in the One and Two-Week Schools for farmers.

In concluding this report I may say, as to the number of high schools having agricultural courses, Michigan compares favorably with other states. Many of the states now offer a special subsidy to schools introducing industrial courses. This gives them a slight advantage as to the number of schools, but notwithstanding this we have been able to maintain a high percentage. Public sentiment seems to be developing in favor of Industrial Education and, particularly, Agricultural Education. This means that the support of the people will more and more be shown in the direction of an intelligent rural population.

Respectfully submitted,
WALTER H. FRENCH,
Professor of Agricultural Education.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DIVISION OF EXTENSION WORK.

President F. S. Kedzie, Michigan Agricultural College:

Dear Sir—The extension service of the College for the year ending June 30, 1916, has been carried on under sixteen projects as follows:

1. Administration.
2. County Agricultural Agents.
3. Home Economics.
4. Extension Schools.
5. Junior Extension Work or Boys' and Girls' Clubs.
6. Farm Crops.
7. Live Stock.
8. Horticulture.
9. Potatoes and Vegetables.
10. Upper Peninsula Work.
11. Farm Management Demonstrations.
12. Control of Insect Pests.
13. Household Engineering.
14. Forestry.
15. Markets.
16. Farmers' Institutes.

Projects Nos. 1 to 13 inclusive, of this list, were approved by the Secretary of Agriculture and carried on under the Smith-Lever Act.

Projects Nos. 14, 15 and 16 were conducted under College funds. Each of these projects is a definitely planned piece of work in charge of a specialist or leader. The reports for the various projects as submitted by the leaders follow this report.

Publications. The printing and distribution of extention bulletins on agriculture and home economics are provided for in the Smith-Lever Act, five per cent of the funds being available for this purpose. This Act also grants the Extension Director the free use of the mails for extension publications.

During the year a series of extension bulletins was established and five numbers issued. These bulletins will be distributed to the regular mailing list, through county agents, at extension schools and meetings, and through teachers in the public and high schools.

An additional series of bulletins for the Junior Extension Work has been established for the purpose of sending follow-up instructors to the members of the Boys' and Girls' Clubs.

The following table gives a complete list of extension publications for the fiscal year:

EXTENSION BULLETINS.

Title.	Pages.	Edition.	Author.
No. 1, Inoculation with Nodule-forming Bacteria	4	10,000	Ward Giltner.
No. 2, The Babcock Test	12	40,000	C. E. Newlander.
No. 3, Some Seed Potato Questions Answered	4	40,000	C. W. Waid.
No. 4, The Home Vegetable Garden	36	20,000	C. W. Waid.
No. 5, Standardization and Group Classification of Potato Varieties for Michigan	16	20,000	C. W. Waid.

CLUB BULLETINS.

No. 4, Organization of Clubs	24	10,000	E. C. Lindemann.
No. 4, Supplement to Club Bulletin No. 4	8	10,000	E. C. Lindemann.
No. 5, Pork Production	16	10,000	G. A. Brown.
No. 6, A Small Poultry House and Hints on Poultry Raising	16	10,000	C. H. Burgess.
No. 7, Corn Growing	16	10,000	V. M. Shoesmith.
No. 8, Hints on Home Gardening	8	10,000	C. W. Waid.
No. 9, Garment-making for Girls	56	20,000	Paulina E. Raven Anna B. Cowles

The following resignations and appointments took place during the year:—

Resignations.

H. E. Larson, Extension Specialist in Farm Crops—Dec. 1, 1915.
O. K. White, Extension Specialist in Horticulture—Dec. 31, 1915.
C. A. Tyler, Extension Specialist in Forestry—Mar. 1, 1916.
C. B. Cook, County Agent, Allegan—Mar. 1, 1916.
J. W. Chapin, County Agent, Branch—May 15, 1916.

Appointments.

I. K. Maystead, Extension Specialist in Farm Crops—July 1, 1915.
D. B. Whelan, Extension Specialist in Insect Pests—July 1, 1915.
Anna B. Cowles, Extension Specialist in Home Economics—Sept. 1, 1915.
Margaret Justin, Extension Specialist in Home Economics—Sept. 1, 1915.
J. N. McBride, State Market Director—Nov. 1, 1915.
J. H. Carmody, Extension Specialist in Horticulture—Feb. 24, 1916.
C. B. Cook, Asst. to State Leader of County Agents—Mar. 1, 1916.
R. H. Elsworth, Asst. to State Market Director—May 1, 1916.
C. A. Spaulding, Asst. to State Agent, Boys' and Girls' Clubs—July 1, 1916.
J. A. Petrie, Extension Specialist in Horticulture—July 1, 1916.

County Agents.

L. R. Walker, Marquette—July 1, 1915.
C. V. Ballard, Dickinson—July 15, 1915.
C. L. Coffeen, Lenawee—August 23, 1915.
R. G. Carr, Ontonagon—November 29, 1915.
C. H. Knopf, Cheboygan—December 1, 1915.
D. L. Hagerman, Ottawa—January 1, 1916.
R. V. Tanner, Mason—February 16, 1916.
R. L. Olds, Muskegon—March 1, 1916.
T. A. Farrand, Van Buren—March 1, 1916.
David Woodman, Alpena—March 20, 1916.
Alfred Bentall, Allegan—April 18, 1916.
H. J. Lurkins, Berrien—May 1, 1916.
C. L. Nash, Branch—July 1, 1916.
E. G. Amos, Schoolcraft—July 1, 1916.
E. B. Hill, Menominee—July 1, 1916.
Frank Sandhammer, Manistee—July 1, 1916.

STATISTICAL SUMMARY.

Project.	No. meetings and demonstrations.	Attendance.
Administration	14	....
County Agents (See Statistical Summary, County Agents' Report.)		
Home Economics	45	4,097
Canning demonstrations	74	....
Home Economics and Agricultural schools	72	4,612
Boys' and Girls' Clubs	131	10,429
Farm Crops (505 farms visited)	97	4,111
Live Stock (4 mos.)	22	800
Horticulture (102 farms visited)	68	1,085
Potatoes and vegetables (254 farms visited)	64	3,326
Upper Peninsula	138	10,879
Demonstration train in U. P.	75	8,640
Farm Management Demonstrations:		
Number using account book	....	943
Records taken	....	422
Control of Insect Pests	82	721
Household Engineering	78	1,552
Forestry (38 farms visited)	9	1,475
Individual farms visited by specialists	....	1,031
Lectures by others than Extension staff	137	10,221
Judges at meetings and fairs	97	....
Farmers' Institutes	548	179,210

During the year it has continued to be the policy of the Extension Division to emphasize the demonstration features of the work. In a large measure the field demonstrations are conducted by the farmers themselves under supervision from the College, and results show that this is the most efficient means of securing the adoption of better methods into actual practice on the farm.

As far as possible the work done during the winter is followed up during the growing season with these field demonstrations, and periodically field meetings are called to bring the attention of others in the community to whatever is worthy of observation. Such observation trips often embrace a large number of places and people and take the form of excursions to see field plats of pedigreed grains, legumes or fertilizers;

herds of special excellence; methods of controlling diseases and insects; equipment for household water supply and sewage disposal; drainage systems; farm buildings, and many other farm methods and equipment.

In all the service offered it is the aim to help both organizations and individuals to do things for themselves rather than to do things for them. Wherever work is done with individuals on special problems those problems are handled in the way that will be of benefit to the community as well as educational to the individual.

In all such matters as sale of products, purchase of supplies, control of disease, surveying drains, farm construction, etc., it is the function of extension workers to teach farmers how, and develop in them business ability through experience rather than to do things for them.

Working with groups and organizations has become the standard method of reaching the large numbers desiring the services of extension workers. The size of the State and the great numbers of rural people make working with individuals inefficient. However, in dealing with groups, special effort is made to secure proficiency on the part of the most adaptable individuals in order that others may later learn from them. To make such work of permanent value, the great need, both in the small neighborhood groups and in the wide community organization, is for local leadership. Such leaders are the permanent point of contact between the service of the College and that community unit.

Many leaders are to be found within present farmers' organizations such as the Granges, Farmers' Clubs and Gleaners, and also within rural schools and churches. Much has been done by the various institutions of the State in developing this leadership, but great effort must be continued to bring about a realization of the opportunities for development along every line in rural community life. The winter short courses, the summer school and summer conferences, farmers' week, and other College activities are assisting invaluably in this work but training in rural leadership should be given emphasis at every opportunity.

The conservative and practical extension work done in former years has effectively prepared conditions for the more rapid growth under the Smith-Lever Act. There are still many communities where little is known of the extension service of the College, but through successful work in adjacent regions our methods and purposes are becoming better known and appreciated. The work is not crowded upon people where there is no desire for it, and it is most encouraging to learn from the extension staff that this desire develops rapidly in such regions as the work becomes more fully understood.

In accordance with the terms of the Smith-Lever Act, the work for the succeeding year has been planned in project form and submitted to the Secretary of Agriculture for approval. Projects Nos. 1 to 14 as already given were revised according to the experiences of the year and have been approved. Projects Nos. 15 and 16 will be continued on College funds.

Very truly yours
R. J. BALDWIN,
Extension Director.

East Lansing, Mich., June 30, 1916.

REPORT OF COUNTY AGRICULTURAL AGENT WORK.

BY DR. EBEN MUMFORD.

INTRODUCTION.

In reporting the work of the County Agricultural Agents for the first three years a rather extensive description of the various activities undertaken was given. The work has been continued as outlined in former reports and therefore it seems better to confine this report principally to a statement of progress made and results accomplished.

The development that has taken place in the county agricultural movement in Michigan this fiscal year can be measured in some of its phases while in others only description can be used. While some results can be stated statistically, other features and results do not lend themselves to the statistical method. There are several standards by which county agricultural agent work may be measured or terms in which it may be described. Some of the standards which may be noted are: counties that have organized and are taking the usual preliminary steps to secure an agent; increase in membership and interest, in the organizations through which the work can be carried on most effectively; improvement in the financial support of the movement; increase in the results on the different projects adopted.

COUNTIES BEGINNING AGRICULTURAL AGENT WORK THIS YEAR.

There are now twenty-six counties having county agricultural agents. Thirteen have begun work this year. This means that within the year the number of counties having agricultural agents has been doubled. To create a sentiment favorable enough to warrant beginning this work and to secure the funds required of the county to support it, are in themselves not easy matters and the fact that this has been done in thirteen counties in one year demonstrates that the work has proved its value and justified its existence, and that the people of the counties have taken a deep interest in this movement.

CHRONOLOGICAL STATEMENT OF THE DEVELOPMENT OF COUNTY AGRICULTURAL AGENT WORK.

County.	Agricultural agent.	Date of beginning.	Address.
Alpena	H. G. Smith	July 1, 1912	Alpena.
	David Woodman	March 20, 1916	
Iron	R. G. Hoopingarner	Sept. 1, 1912	Crystal Falls.
Kent	J. H. Skinner	Sept. 16, 1912	Grand Rapids.
	H. G. Smith	Jan. 1, 1916	
Kalamazoo	Jason Woodman	Nov. 1, 1912	Kalamazoo.
Allegan	C. B. Cook	March 1, 1913	Allegan.
	Alfred Bentall	April 20, 1916	
St. Clair	L. V. Crandall	March 1, 1913	Port Huron.
	Clark L. Brody	April 1, 1915	
Branch	J. W. Chapin	April 1, 1913	Coldwater.
	C. L. Nash	July 1, 1916	
Saginaw	Earl P. Robinson	April 1, 1913	Saginaw.
Houghton	L. M. Geismar	June 1, 1913	Houghton.
Newaygo	H. B. Blandford	June 10, 1913	Fremont.
Gogebic	J. F. Kadonsky	July 1, 1914	Ironwood.
Wexford	J. F. Zimmer	Oct. 1, 1914	Cadillac.
St. Joseph	J. M. Wendt	Dec. 15, 1914	Centerville.
Marquette	L. R. Walker	July 1, 1915	Marquette.
Dickinson	C. V. Ballard	July 1, 1915	Iron Mountain.
Lenawee	C. L. Coffeen	Aug. 23, 1915	Adrian.
Ontonagon	R. G. Carr	Oct. 10, 1915	Ontonagon.
Cheboygan	C. H. Knopf	Dec. 1, 1915	Cheboygan.
Ottawa	D. L. Hagerman	Jan. 1, 1916	Grand Haven.
Mason	R. V. Tanner	Feb. 16, 1916	Scottville.
Muskegon	R. L. Olds	March 1, 1916	Muskegon.
Van Buren	T. A. Farrand	March 1, 1916	Paw Paw.
Berrien	H. J. Lurkins	May 1, 1916	Benton Harbor.
Manistee	Frank Sandhammer	July 1, 1916	Manistee.
Menominee	E. B. Hill	July 1, 1916	Menominee.
Schoolcraft	E. G. Amos	July 1, 1916	Manistique.

FINANCING THE WORK.

In addition to the counties that have organized and employed agents there are at least twenty-five other counties that are in various degrees of preparation for the work. In Presque Isle county the Board of Supervisors has appropriated the county's share of the funds needed, but the funds apportioned for county agent work by the College and the U. S. Department of Agriculture were exhausted when the twenty-sixth county organized and secured an agent. However, any other county may begin work at any time if in position to finance it until College and Federal funds are available. As a rule the State Leader or Assistant State Leader visits counties desiring agents and explains the work in several sections of the county. When there is enough interest on the part of the farmers to warrant the starting of this kind of work, a county organization is formed and methods decided upon for raising the county's share of the funds.

In all of the counties except three the Boards of Supervisors have this year appropriated nearly all of these funds. In one of these three counties the Supervisors are appropriating about half of the funds, and in the other two the funds are raised by subscription. The appropriations of the Supervisors for this year vary from about $1200 to $2000. The financial tendency of the movement locally is strongly in the direction of having the county governments raise the county's share of the funds through appropriations by the Supervisors. This seems to be the equitable method of distributing the costs as the benefits accrue to all classes and occupations.

ORGANIZATION.

There has been considerable progress in organization and this has been largely in the direction outlined in the report of last year. This year greater efforts have been made to secure an organization in every community, with which the agricultural agent can work. A community is a fairly well defined territory and is naturally the social and economic unit for agricultural agent work. The boundaries of the township sometimes coincide with the boundaries of the community, but as a rule it has not been found possible to make the township the unit for local organizations. The agricultural community generally has a town or small city as the central meeting place where the people come regularly to sell their farm products and to buy the usual articles consumed; this town or city is the banking center and, to a very large extent, the educational, religious, and social center. Within a certain radius of this center, therefore, the people are acquainted and have many interests in common. Such a center is, consequently, the natural place of assembly and provides the logical setting for organized effort, whether of a community organization as a whole, or of organizations for forwarding specific enterprises such as potato or bean growers' associations, pedigreed seed associations and the various kinds of live stock organizations. At the community center it is easier to have regular meetings and out of such conferences there is gradually growing a consciously formed agricultural program by means of which the problems of the community may be worked out cooperatively and systematically. The form of this organization varies according to local conditions, but some kind of an organization is essential in order to secure the largest results. The interest and assistance of a much larger number of people is being secured by apportioning the various phases of the work to committees and by uniting the efforts of the different local organizations in the solution of problems common to all the people of the community.

The county organizations are being greatly strengthened by the growth of the community organizations. There are many agricultural problems which the community has to meet but which are more far reaching than community limits; the community organizations, therefore, need to be closely related to a county organization and to the state and national forces interested in the problems of agricultural development.

Moreover, as stated in our report for April, 1916, such a system is essential if the agent is to accomplish what devolves upon him. The reports of the men show the rapidly growing demands upon their time for assistance in all sections of the counties and for almost every conceivable agricultural need. To meet these increasing demands branches of the County Farm Bureaus are being formed in the various communities of the counties as rapidly as possible and the work is being carried on through groups and committees. It is only by this group method that the numerous calls can be answered and that the efforts of the farm agents can be made of largest benefit to the people of the county. Moreover, these community organizations affiliated with a county organization furnish the machinery not only for reaching more people but also for standardizing their products and thus preparing the way for more advantageous marketing as well as for more efficient and economical production.

RELATION OF THE COUNTY AGRICULTURAL AGENTS TO THE OTHER PHASES OF THE EXTENSION SYSTEM.

By virtue of his acquaintance with local conditions and people and with the machinery of organization just described, the county agricultural agent becomes the logical leader and director of all Extension work within his county. By his efforts, through the organizations of the county, it is possible to make the most effective use of the time of the specialists of the College, the State and the Federal Government. He is in position to form a complete itinerary of the county that will bring the specialists direct to the problems to be solved. He not only can arrange the schedule of appointments or meetings, but he is also in position to announce the coming of the specialists, through all the different channels of communication within the county, and so to bring these opportunities to the attention of the largest number of people. He becomes a specialist upon the agricultural needs of the county and can coordinate all extension efforts and forces within it in such a way as to make them lead toward the development of the county agricultural program.

It will therefore be seen that county agricultural work is not a one-man movement but is a system through which many people within the county cooperate in developing their agriculture and, when necessary, call for the assistance of specialists.

It is not possible in this report to describe specifically or fully the work that the specialists are doing in cooperation with the agricultural agents, but this is given more in detail in the reports of the specialists. However, it is a pleasure to acknowledge the valuable assistance which they are giving and to state that much that is reported here has been accomplished with their cooperation.

SOILS.

Problems: In all of the counties the soil problems in some of their phases demand much of the time of the agricultural agents. The chief problems as reported by them are: planning drainage systems, providing humus, correcting acidity, growing legumes adapted to the varied conditions, demonstrating the profitable use of commercial fertilizers and economical methods of clearing land.

Soil Surveys, Analyses and Experiments: As a foundation for the solution of the soil problem, a very important project has been undertaken in several counties this year in cooperation with the Department of Soils of the College. A survey has been made to determine the different soil types of the county, samples have been taken and analyses made as a basis for establishing lime and fertilizer experiments on these different soil types. In starting the experiments based upon this data the County Farms have been used in some instances. While this project has not been established long enough to make it possible to know the results, still it is believed that it is in the right direction and that it will prove to be fundamental as a method of approach in the solution of the more intricate phases of these basic agricultural problems.

Use of Fertilizers: Some excellent demonstrations in the use of fertilizers have been made this year. Particularly is this true of the use of phosphoric acid on soils deficient in this element. In several demonstrations on wheat the crop was increased from 100% to 300% by the use of about 200 pounds of phosphoric acid per acre. Demonstrations in the use of phosphoric acid on oats at the rate of 200-300 pounds per acre showed an increase of from 40% to 300% in the crop. On corn the use of fertilizer also gave good returns on the investment.

In some counties vetch is grown extensively and a large part of the crop used for green manuring. On one demonstration of the value of vetch used as a green manure crop the yield of corn was doubled.

Some very valuable results have also been obtained from the use of muck on light soils and in one instance reported the muck gave better returns than the same amount of stable manure.

The chief value of these demonstrations lay in the fact that meetings were held at these farms so that the farmers could see exactly what had been accomplished and by what methods. In this manner the better practices are being gradually spread.

Correcting Acidity: Demonstrations in the case of lime and marl have been increased and more widely distributed. The results of these demonstrations have been so pronounced as to convince even the most skeptical of their value. The reports of the agents show that the application of lime or marl in sufficient quantities has frequently given an increase in yields of alfalfa of from 50 to 75 per cent. By means of meetings held at such demonstrations these results have been made known to the farmers. There was a large increase in the use of lime during 1915; for that period the agents reported 13,687 tons used, as compared with 8,000 tons in 1914. They also report that 61 marl beds were located and developed.

In several counties the Farm Bureaus have purchased the apparatus for testing soils for lime requirements, recommended by the Experiment Station Chemist. By the use of this and the litmus test a large number of samples of soils has been tested for farmers preparing to grow legumes and particularly alfalfa, One agent reports testing 177 samples in two consecutive months.

Drainage: In six counties drainage demonstrations have been made leading projects this year. As the growing season last year and the early part of this was exceptionally wet it afforded a strong stimulus to farmers having lands insufficiently drained to give more than the usual amount of attention to their drainage problems. As a result the drainage demonstrations have been carefully watched by the farmers and many of them have begun to provide better drainage for their farms.

FARM CROPS.

The organizations that are being formed serve several purposes with reference to crops. Through these organizations pedigreed varieties are being introduced on a much larger scale and on a community basis. These members meeting together help one another solve their problems of production and distribution. It not only means better and more economical production but really prepares the way for successful marketing in that varieties are standardized and a high class product is produced in car lots. Since January 1, 1916 the formation of 13 pedigreed seed associations has been reported.

Through the local potato associations the number of varieties is being reduced to two or three of a standard commercial type. The demonstrations in the treatment of seed are helping to make this practice much more common and through inspection of seed plots diseases are being eliminated and the higher yielding hills selected. The association work is preparing the way for reducing waste and for much more successful marketing.

In addition to the standardization of the varieties of potatoes, which is proceeding quite satisfactorily, mention should also be made of the standardization that is taking place in the wheat and oat crops. The superiority of Red Rock Wheat has now been fully demonstrated in several counties and plans have been formed by a number of communities for adopting it as their leading variety. Community action in this respect will help to keep the wheat pure and at the same time furnish to the millers, in quantities, a wheat which has met their approval. Also through community action the growing of Worthy and Alexander oats is becoming much more general.

Through the marked results shown in the oat-smut control demonstrations last year, there is a much more extensive use of the formalin treatment this year and in some counties the agents report that the practice has become quite general. In one county where a very active campaign was conducted it was estimated from the amount of formalin used that about three-fourths of all the seed was treated, or an amount sufficient to sow 20,000 acres.

Because of the extraordinary amount of poor and unripened corn in the crop of 1915, there was difficulty in getting good seed this spring and this caused unusual activity in seed-testing. Campaigns were carried on extensively through the schools and in the various communities. Through the press and by means of circulars and posters information regarding sources of good seed was given; the necessity of testing all seed was emphasized and the method explained.

The increased use of lime and marl has been largely a foundation for the growing of legumes. This has resulted in a greater acreage and higher yields. The successful methods of growing alfalfa are gradually becoming general. Much more care is being taken to comply with all the conditions that have been demonstrated to be necessary for success. The reports of the agents indicate that there has been an increase in the acreage of alfalfa of about thirty per cent.

The use of sweet clover has been gaining in favor, particularly for the lighter soils and as a preliminary step in the growing of alfalfa. It is also being grown for seed. As the more successful methods of growing it become established through demonstrations, it promises to occupy an important place among the legumes.

Soy bean demonstrations have been increased and more widely distributed, with a resultant increase in the acreage grown by the farmers. The agents report about 300 acres planted at their suggestion in 1915.

The efforts to secure seed beans more resistant to blight and freer from anthracnose have been continued. Comparisons are being made of Early Wonder, Idaho-Grown Michigan and Michigan hand picked seed.

HORTICULTURE.

In horticulture the demand for the assistance of the county agent and the specialist has constantly increased. As in preceding years demonstrations in pruning, spraying, thinning, grading and packing have been conducted. More requests have been made for help in overcoming fruit diseases and insect enemies than for any other phase of fruit-growing.

Spraying, while a long established custom in some localities, has been found to be almost entirely absent in others. The county agents have shown the desirability of preserving the farm orchard and the possibility of profits from clean, well cared for fruits.

In one county an orchard survey was made as a basis for future orchard work. In another a fruit tree campaign interested farmers in planting 10,000 fruit trees, chiefly apples.

In one county where marked improvement has been shown in the methods of production of fruit, the agent attributes much of the change to the interest that has been taken in community exhibits of fruit and to the stimulus given by winning premiums at the state exhibits.

In six counties demonstrations in spraying for control of blight in celery have been started. In one county twelve sprayers are reported to have been purchased for controlling late blight in celery as a result of the demonstrations given this season; nine of these were purchased cooperatively. Also, these demonstrations so won the confidence of the truck growers in that vicinity that they are planning for extensive spraying another year. Special attention has been given to the growing of onions and to truck crops in general wherever these crops occupy the attention of large numbers of people.

LIVE STOCK.

Much attention has been given to the different live stock projects this year and excellent results have been achieved. The reports show that ten cow-testing associations have been formed and one reorganized. In addition to the testing that is being done through associations, several of the men have given considerable time to making tests themselves and to conducting testing demonstrations. There have been ten community breeding associations formed since Jan. 1, 1916. A live stock census was taken in two counties. The dairy picnic was used in one county to good advantage. About forty dairy cattle were brought from different sections of the county and a judging demonstration given. This was followed by a judging contest in which a number of farmers took part. The attendance was large, the interest keen and the demonstration and contest have proved to be strong incentives to better dairying.

Control of Live Stock Diseases: In no other phase of the whole movement is a thoroughly organized community so essential or concerted action so imperative as in the control of transmissible animal diseases. Repeatedly it has been demonstrated that the control of hog cholera is a community interest and can be checked or eliminated only when the community acts as a whole and acts quickly. That this is possible only through an effective organization has been well exemplified. With neighborhood standards of sanitation for farm buildings rising, with a neighborhood conscience quickened to the point of acting for what is beneficial to the group, including a sacrifice of personal convenience or temporary personal interests when necessary, the man who is careless of his premises, who would conceal infection rather than report it and get rid of it, and who thereby becomes a source of danger to the community, is no longer tolerated by his neighbors. Furthermore, as the control of the disease comes to be regarded as a community interest, the community assumes a share of the expense of the treatment as is shown in two or three counties where serum has been furnished by the township to be used as the agent may direct and without any charge to the farmers.

As a result of the persistent organized efforts to control hog cholera during the season of 1915 in the four sourthern counties where losses had been greatest in preceding years, the reports of the agents show that hogs approximating in value $130,000 were saved to the farmers of these counties. In regard to hog cholera since January 1, 1916 three counties report some inspection and disinfection carried on merely as precautionary measures, no cholera having occurred this year in either county. In a fourth county there has been one outbreak traceable to manure drawn from stock cars. Of the four southern counties above mentioned two report six outbreaks each; from one comes a report of sources of infection as follows: carried over from previous years, three, (one of these was spread by flood conditions); hogs brought in from adjoining county to a local slaughter house, one; carried to farm by stock cars on railroad passing farm, one; from feeding garbage, one. In the third county a systematic campaign for the control of cholera has been carried forward all year; although many suspicious cases have been reported only a few of these have been found to be cholera. In the fourth county reporting, not a single case is now known to exist.

The most encouraging feature of all this season's work is the fact that in not a single instance has any spread of the disease been found.

The cooperating parties in the control of this disease are the Bureau of Animal Industry of the United States Department of Agriculture, the State Live Stock Sanitary Commission, the Farm Bureaus and Agricultural Agents of the counties.

The only other disease that has claimed enough attention to be noted has been tuberculosis. At the conference of the county agricultural agents at the College February 28, one session was given largely to the consideration of the relation of the County Agent to the use of the tuberculin test. A committee was appointed to formulate a policy in regard to this and the report of that committee was adopted by the agents. In brief it seemed to be the consensus of opinion of the men present that the agent's attitude in regard to the use of the tuberculin test should be largely an educational one and that the consideration of the common good should be the basis of his activities in this respect. He should try to secure the cooperation of the veterinarians of his county in an organized effort to control or eradicate bovine tuberculosis. Experience shows that as a rule the veterinarians are willing to cooperate with the agents in this important work. Where they are not, it was believed that the good of the community and of the county should be the first consideration and that the agent should do all he could to create a sentiment favorable toward action that would eradicate the disease and protect the health of the people of the county and of all the consumers of milk from the county.

Interest in eliminating tubercular animals from dairy herds is general. In some counties farmers have been assisted in familiarizing themselves with making the tests. By this means and by the general building up of better dairy herds, the weaker animals are being removed. Interest in pure milk is being stimulated by talks in the schools and before mothers' clubs.

FARM MANAGEMENT DEMONSTRATIONS.

The interest in the farm management demonstrations has been increasing as will be seen from the report of the Farm Management Demonstrator. It is believed that the value of this work will become more apparent as the county agricultural agent work is developed. The whole tendency of this movement is toward a well organized county agricultural program, and in such a program the study of the farm as an organization of specific enterprises has a very important place. One of the most encouraging and gratifying features in the progress of the farm management work this year has been the interest that has been taken in farm accounting and in the use of the farm account book. In the three main branches of any business—production, accounting and distribution, accounting is absolutely essential for an intelligent direction of the business.

BOYS' AND GIRLS' CLUB WORK.

The relation of the county agent to boys' and girls' club work is largely that of an advisor on the technical phases of agriculture, but he is vitally concerned in the progress of the work as an organized movement. It is a source of development of rural leadership and of interest in the opportunities of rural life and of an intelligent appreciation of them. As an advocate of a program for permanent agriculture within his county he is committed to a policy that will hold the interest of the boys and girls and assure their training in team work, upon which much of the future development in agriculture depends.

According to the reports of 17 agents, 101 clubs have been formed since January 1, 1916.

THE MARKETING OF FARM PRODUCTS.

A large part of the work of the agents this year has had a direct or indirect bearing on the buying and selling operations of the farmers. Almost every successful organization, whether formed for marketing or not, exercises a helpful influence in this direction because it furthers acquaintance among farmers and accustoms them to acting collectively. Moreover, in practically all the projects adopted, one of the chief ends in view has been more advantageous marketing. Likewise, one of the keenest interests the farmers have had in the movement has been in the aid that might be given toward more satisfactory marketing, and the agent's principal point of contact in dealing with them has often been in relation to questions of buying and selling. But, as a rule, there are many preliminary steps before the farmers of a community are in position to take advantage of the best markets in an economical manner. Successful buying and selling implies products of definite standards and grades in quantities sufficient to be handled in car lots, and this calls for community action and organization.

As an outcome of potato association work, two agents report the sale of 300 bushels and 400 bushels, respectively, to be used for seed, to the members of a Farm Bureau in another county in Michigan. One of these counties also sold three car loads of potatoes for seed in Ohio, Indiana and Illinois, the sales being made through the Farm Bureaus in those states.

The work of the community breeding associations in relation to marketing has been chiefly in purchasing better stock, a large number of sires having been bought in this way and also some pedigreed and some good grade cows. As a result of this kind of organized live stock work one agent has reported a sale of registered cattle, the first of its kind in his county, and another the selling of a car load of dairy cattle. One agent assisted his farmers in the purchase of four car loads of cattle for grazing.

The agents have been in close touch with the live stock shipping associations, of which a large number has been formed in Michigan in recent years. In two counties the agents have been confronted with the problems of marketing milk, and through their efforts these have been taken up by committees of the Farm Bureaus.

Exchange lists of products wanted or for sale, are issued by the agents of several counties and these have proved helpful; in one county a Buyers' and Sellers' Association has been formed.

Three associations for the marketing of fruit have been reported as formed since January 1, and in the other counties where fruit growing is important the agents have aided in reorganizing associations or in strengthening them through federation. The work of all these associations is being made much more effective through the demonstrations which have created a greater interest in fruit of good quality, carefully graded and packed. Through the local and state exhibits the counties are being brought into closer touch with the best markets and by other means of advertising a greater demand is being developed for fruit.

An interesting illustration of cooperation of different interests in marketing is that of the method followed by one county in adjusting a difficulty in regard to prices of wheat between farmers and millers. Through the offices of the agricultural agent, committees from the millers, the Farm Bureau and the Association of Commerce met together for discussion of their differences. The outcome was the adoption of a cooperative plan satisfactory to all parties.

INSTITUTES AND ONE-WEEK SCHOOLS.

During the winter months the institutes and one-week schools occupy a large part of the time of the county agents. In January, February and March twenty agents reported a total of 874 meetings with an attendance of 57,230. Since the inception of the county agent movement the tendency has been to make meetings of this character a part of the regular agricultural program of the county, and at the June conference of the agents a policy to this effect was formulated by a committee of the agents and adopted by the conference. The Institutes and Schools furnish the best opportunity for a careful study of the methods and results of the demonstrational work; also the best opportunity for deliberation upon the projects to be adopted for the new year. The significance of these meetings in the agricultural development of a county is greatly enhanced when they are made to contribute directly to the agricultural program of the county and to certain definite projects continuing through the year or until satisfactory results are obtained.

CONFERENCES.

During the year three conferences of the agents were held at the College and two district conferences in the Upper Peninsula. These conferences afford an excellent opportunity for exchange of ideas and experiences and for consideration of the leading projects and methods. At one of the conferences this year attention was concentrated largely upon methods of controlling animal diseases, and at another upon the problems of marketing farm products. One of the meetings of the agents was held at the time of the Fourth Annual Country Life Conference. The program of this conference dealt with social and economic problems of rural life with which the agents are concerned.

FIELD WORK OF ASSISTANT STATE LEADER AND STATE LEADER.

An appointment which promises much for the development of the work in Michigan and which supplies an urgent need that had existed for some time, was that of Mr. Charles B. Cook to the position of Assistant State Leader. Mr. Cook closed his work as County Agricultural Agent in Allegan County, March 11, and assumed the duties of the new office March 20.

The field work of both the State Leader and Assistant State Leader has been chiefly as follows:

a. Explanation of County Agricultural Agent work in counties not having agents.

b. Assistance in organizing new counties and in selecting agents.

c. Helping to strengthen organizations in counties already organized.

d. Consultation with Farm Bureau officers and committees, and agricultural agents in regard to projects and methods.

e. Attending and addressing meetings in the counties for the purpose of forwarding some definite project.

f. Study of methods and results of work connected with the various phases of the County Agricultural Agent movement.

The Assistant State Leader has given most of his time to work in the field. Twenty-nine visits have been made to the county agents; this has included trips to twenty-six demonstration farms for inspection and study of that work; it also included assistance in counties starting the work. He has attended 23 meetings totalling 1,280 people and has addressed most of these meetings in relation to some phase of county agent work.

During the year the State Leader has made 80 visits to the county agents and with them has visited 57 demonstration farms. On account of the large number of new counties organized this year much of the time has been needed for them. In the interest of the work in the organized counties and in those just starting, he has addressed 119 meetings with an attendance of 18,575.

In behalf of all those directly connected with the work the State Leader wishes to acknowledge the assistance given by different members of the faculty of the College and by members of the U. S. Department of Agriculture in the conferences, in field work and in various other ways; also the assistance which has been rendered by the cooperation of many organizations in the State, with the County Agricultural Agent movement.

A statistical summary of some phases of the work concludes this report. Since the reports of the agricultural agents are now made on the basis of the calendar year and not the fiscal, it is necessary to give two series of statistical summaries, one for all of 1915 and one in part for the first six months of 1916. The first group of statistics has been compiled from their reports for the calendar year 1915. Ten of the reports were for the full year; one for eleven months; one for nine; two for six; and one for four months.

Seventy-five per cent of the agents' time was spent in field work.

STATISTICAL SUMMARY FROM JANUARY 1, 1915 TO DECEMBER 31, 1915.

Work done in relation to the people.

		No. Agts. reporting.
Associations organized for adults	63	14
Membership	2,316	14
Boys' and Girls' Clubs	15	14
Membership	650	14
Meetings addressed	1,046	17
Attendance	58,737	17
Short Courses held	31	17
Attendance	3,560	17
Farm visits made	9,063	17
Calls on agents at office	5,475	17
Letters written	13,700	17
Circular letters mailed	44,008	17
Press articles prepared	373	17
Bulletins distributed	4,593	17

WORK DONE ON SUGGESTION OF AGENT, OR UNDER HIS DIRECTIONS.

			No. Agts reporting
I.	In Home Improvements:		
	Water supply systems installed	46	10
	Lighting systems installed	4	10
	Heating systems installed	2	10
	Home grounds planned	32	10
	Sanitary conditions improved	135	10
II.	With Corn:		
	Farmers selecting seed corn	704	10
	Acres planted with selected seed	3,375	10
	Acres planted with tested seed	5,115	10
	Increased yield in bushels per acre	8	10
III.	With Wheat and Oats:		
	Acres wheat grown	2,164	8
	Increased yield in bushels per acre	11	8
	Farms treating oats for smut	515	8
	Acres oats seeded with treated seed	6,970	8
	Increased yield of oats in bu. per acre	14	8
IV.	With Hay and Legumes:		
	Acres of hay grown	840	12
	Increased yield of hay, tons per acre	½	12
	Acres alfalfa grown	7,697	12
	Acres sweet clover	477	12
	Acres soy beans	300	12
	Acres cow peas grown	33	12
	Acres vetch grown (estimated)	12,500	12
V.	With live stock:		
	Pure bred sires purchased	106	12
	Cow-testing associations formed	6	12
	Cows tested	834	12
	Breeders' associations formed	15	12
	Membership in Breeders' associations	435	12
VI.	With live stock diseases:		
	Animals treated for tuberculosis	557	7
	Hogs vaccinated for Cholera	3,776	7
VII.	In relation to soils:		
	Tons of mineral fertilizers used	818	11
	Local sources of limestone developed	61	11
	Tons of limestone used	13,687	11
	Acres of hay or grass land top-dressed	750	11
	Acres of legumes used for green manuring	5,680	11
	Acres of other crops so used	1,571	11
	Acres for which drainage was planned	1,905	14
	Crop rotations planned	285	
VIII.	Farm Buildings:		
	Farm buildings planned	115	14
	Silos constructed	657	14
IX.	Improving farm business:		
	Farm analysis records taken	382	8
	Farmers induced to keep accounts	130	8
	Cooperative associations organized	17	8
	Business done by associations	$513,150	8
	Saving by associations	62,800	8

STATISTICAL SUMMARY FROM JANUARY 1, 1916 TO JUNE 30, 1916.

	Jan.	Feb.	Mar.	Apr.	May.	June.	Totals.
Number of agents reporting	18	21	21	22	22	26	....
Field.							
Days in field	342	323	281½	372½	493	389½	2,201½
Demonstrations:							
a. Visited	....	....	....	46	68	137	251
b. Meetings held at	....	....	13	54	65	40	172
c. Attendance at meetings	....	....	424	758	515	906	2,603
Other meetings held	392	238	245	222	161	105	1,363
Attendance	28,586	16,015	12,835	9,985	7,583	5,632	80,636
Farm visits made	382	279	317	1,023	1,465	1,334	4,800
Office.							
Days in office	193	134	210½	137½	148	137	960
Calls on agent:							
Personal	976	559	1,043	1,124	1,050	820	5,572
Telephone	657	514	986	1,197	1,421	1,057	5,832
Articles published in local press	10	9	44	29	48	77	217
Letters written	2,175	1,822	2,216	2,611	2,519	1,735	13,078
Circular letters mailed	135	1,106	1,469	1,603	1,793	1,262	7,368
Bulletins distributed	....	....	4,118	5,328	1,429	1,908	12,783

REPORT OF EXTENSION WORK IN HOME ECONOMICS.

BY PAULINA E. RAVEN.

The extension work in Home Economics for the past year has been carried on by the specialists. The different phases of work which were begun during the first year were continued during the second year. It was gratifying to note the interest taken, results evident, and the reception given when a place was visited for the second time. It is impossible with our present staff to know just the number of people helped and the changes made because of the Extension work in Home Economics. It has not been possible to make many personal visits to farm homes. This form of extension work can best be carried on by a Home Demonstration Agent located in a county.

Extension Schools: During the season from November 1st to April 10th, the specialists were engaged in conducting one-week schools. Thirty extension schools were held in different parts of the State; six of which were second year schools, being held where schools were conducted the previous year.

Total number enrolled	1561
Total number of lectures given	137
Total number of demonstrations given	143

For a more detailed report of the Extension Schools in Home Economics, see "Report of Extension Schools."

Fairs and Community Exhibits. Food products and canned goods were judged at the following fairs: Michigan State Fair, Imlay City

Fair, Eaton County Fair, and Hillsdale County Fair. An attempt has been made to have the fair associations adopt and use a uniform score card in judging the products, in order that the exhibitors may know the basis on which the products are scored. Canning demonstrations, demonstrating the Cold Pack Process of Canning, were given at the following fairs: Calhoun County Fair, Jackson County Fair, and Lenawee County Fair. The following Community Fairs were visited where judging was done, and a short address given on Extension Work in Home Economics at each place: Merle Beach, Scotts, East LeRoy. In attending the fairs we have been able to meet people from different sections of the State and to interest them in Extension work.

Associations and Summer Conferences. Addresses and demonstrations were given at one or more sessions of the following conventions and organizations:

State Federation of Women's Clubs.
National Potato Growers' Association.
Conference of Extension Workers of the North Central States.
State Nurses' Association.
Farmers' Week (3 lectures, 1 demonstration).
Housekeepers' Conference (5 lectures, 3 demonstrations.)
Conference for Rural Leadership (1 lecture, 1 demonstration).
Home Economics Teachers' Conference.
Home Economics Section of the State Federation of Women's Clubs.

Girls' Club Work. In February Miss Anna Bryant Cowles, one of the members of the staff, took up the Junior Extension work for girls, because of the need for assistance in that branch of extension work. A bulletin on Garment-making has been prepared for use in girls' clubs.

Canning Demonstrations. Considerable time and attention has been given to demonstrating the Cold Pack Process of Canning. 1st, To conserve the waste in the gardens and orchards; 2nd, To make a greater variety in the diet in the winter and early spring, when fresh fruits and vegetables are not obtainable. 3rd, Because the price of canned products will have advanced this coming season, to the point where many cannot afford to purchase them. Single canning demonstrations have been held in thirty-one different communities, exclusive of those given at fairs and in connection with the one-week schools, and there has been a total attendance of 2,702 women.

Two members of the extension staff made a trip to the Upper Peninsula in March. Extension schools were held in six different localities. In May, a petition signed by one thousand women was sent to the office of the Extension Director asking that an Extension Specialist in Home Economics be placed in charge of the work in the Upper Peninsula with headquarters at Marquette. This request came as the result of the work done and the interest created by the members of the staff and the other Extension Specialists in the Upper Peninsula. Miss Margaret Justin, one of the specialists who has assisted in carrying on the work for the past year, has been assigned to this position.

State Nurses' Association. The members of the Home Economics Extension department met with the State Nurses' Association at their annual meeting held at Kalamazoo in May. The purpose of the Home

Economics Extension work was presented at the meeting. The State Nurses' Association will cooperate with the Extension Specialists in presenting the lectures and demonstrations on Health Day in Extension Schools, and Better Babies Week.

Rural Home Clubs. As a means of follow-up work, two clubs were organized in rural communities to carry on the work of the Extension Schools. These clubs were organized at the request of the members of the schools and will be known as the Rural Home Clubs. The object of the clubs is to encourage sociability while working for the betterment of the homes, and to better homes by systematic study. Monthly meetings are held and a report is made by the Secretary to the Home Economics Extension department after each meeting. Suggested programs have been sent to the clubs together with material for the programs. It is the plan to organize many such clubs during the coming year, because they will be a means of bringing the College in closer touch with the women of the rural communities, and will be a means of continuing the work begun in the Extension Schools.

Bureau of Information. The Bureau of Information was conducted the same this year as last year. Many requests have come in for special diets. Seventy-four diets have been sent out, fifty per cent of these were for diabetic patients. These diets were always made out at the request and in cooperation with the physician in charge of the case.

There is need for some special lines of Extension work for young women, past eighteen years of age. They are too old for the club work and they are not yet in homes of their own. They are asking "What have you to give us?"

SUMMARY.

Total number of schools	30
Total enrollment of schools	1,561
Total canning demonstrations	31
Total enrollment of canning demonstrations........	2,702
Other lectures and demonstrations	23
Total attendance of separate lectures and demonstrations	1,840
Total number of people served	6,103

REPORT OF EXTENSION SCHOOLS.

BY R. J. BALDWIN.

The Extension School is a group of rural people organized into a class, to which a definite course in agriculture or home economics is given over a period of from three to five days, by members of the extension staff. These schools offer an opportunity for more intensive study than is possible in meetings of shorter duration and larger attendance. The purposes of these schools may be briefly stated as follows:

1. To give systematic courses of instruction adapted to local needs.
2. To give those who cannot leave home a chance to take advantage of a course near at hand.
3. To promote greater local interest in local problems by bringing the people together to discuss their common problems.
4. To bring the extension workers into personal contact with the people of the community to the end that plans may be made for carrying out definite demonstrations on local farms and in local homes. This often results in working out a program of a year's work for a local organization which affects the whole community.
5. To interest boys and girls in home project work, and to place them in touch with the Junior Extension Service of the College for further instruction.
6. To keep the farmers and farmers' wives acquainted with the work of the Agricultural Experiment Station, the United States Department of Agriculture, and with the better practices of farmers in other parts of their own State.

The extension workers are in constant association with farmers in various parts of the State, some of whom are successful in one line and some in others. This in addition to their training makes it possible for them to make their courses practical and adaptable to local conditions.

Systematic courses were offered in the following subjects:

Farm Crops.
Horticulture.
Soils.
Farm management.
Dairy husbandry.
Live stock.
Farm and household engineering.
Insect pests.
Animal husbandry.
Home Economics, 1st year.
Home Economics, 2nd year.

The special assistance of Mr. J. A. Waldron and Mr. Ashley M. Berridge in animal husbandry and dairying, and Mr. T. A. Farrand in horticulture, was secured for the season and this made it possible to meet the demand for this type of instruction. The members of the College teaching staff assisted wherever possible, giving courses on special subjects requested.

In counties having county agricultural agents the schools were arranged for by the county agent. In most of such cases the county agent assisted in the instrumental work. An attempt will be made in the future to send sufficient aid to relieve the county agent of this responsibility in order that he may be free to stimulate attendance, perfect the organization of the school and arrange for follow-up work.

The following tables summarize the agricultural and home economics extension schools of the season:

ONE-WEEK AGRICULTURAL EXTENSION SCHOOLS IN 1915-16.

	Average Att.	Total number enrolled.	Lectures given.	Year.	Subjects given.
Albion	25	54	22	1st	Dairying, F. Crops, F. Engineering.
Athens	29	65	20	1st	Dairying, Farm Crops.
Algansee	62	75	17	2nd	F. Management, F. Engineer., Live Stock, Soils
Battle Creek (Convis)	30	35	20	2nd	F. Crops, F. Engineer., Control of Insect Pests.
Berlin	17	25	20	1st	Dairying, F. Crops, F. Engineering.
Beulah	20	30	16	1st	F. Crops, Dairying.
Brethren	17	24	18	1st	Soils & Crops, Live Stock, Horticulture.
Caledonia	34	50	16	3rd	Dairying, F. Crops, Live Stock, Poultry.
Cadmus	10	30	18	1st	Animal Husbandry, Soils & Crops.
Caro-Ellington	18	41	20	1st	F. Crops, Dairying.
China (St. Clair)	36	46	30	1st	Dairying, F. Crops.
Coldwater	14	36	9	2nd	F. Management, Dairying.
Constantine	26	59	19	1st	Dairying, Soils & Crops.
Coopersville	23	45	18	1st	Dairying, F. Crops.
Dowagiac	43	125	22	2nd	Horticulture, F. Crops, F. Engineering.
Durand	21	53	16	2nd	F. Crops, F. Engineering, Insect Pests.
Edwardsburg	31	79	18	1st	F. Crops, Dairying.
Fennville	37	54	12	2nd	Dairying, Soils, F. Crops.
Frontier	28	61	16	2nd	F. Crops, F. Engineering, Live Stock.
Gaylord	20	35	8	1st	Soils and Crops.
Hemlock	14	38	16	1st	Farm Crops, Dairying.
Hopkins	19	30	12	1st	Soils & Crops, Dairying.
Iron Mountain	27	35	18	1st	Dairying, Soils & Crops.
Jasper-Ridgeville	18	25	15	2nd	Animal Husbandry, Soils & Crops.
Kent City	41	56	20	1st	Farm Management, Hort., F. Engineering.
Kochville	16	35	20	1st	Farm Management, Dairying.
Manton	18	35	21	2nd	Soils & Crops, Animal Husband, F. Engineering.
Marshall	14	28	20	2nd	F. Crops, F. Engineering, Insect Pests.
Monroe	37	88	23	1st	Soils, Dairying, House Engineering.
Nelson-St. Charles	22	44	20	2nd	F. Management, Soils & Crops.
New Haven	13	35	16	1st	Dairying, F. Crops.
New Richmond	28	34	12	2nd	Soils & Crops, Dairying.
Petoskey	44	119	18	1st	Dairying, F. Crops.
Quincy	11	25	5	2nd	F. Management, Dairying.
Riley	62	90	16	2nd	F. Crops, F. Engineering, Insect Pests.
Saginaw Township	21	36	14	2nd	F. Management, Poultry, Vet. Science.
Scotts	28	47	20	1st	Farm Crops, Dairying.
Shelby	24	72	17	1st	Dairying, F. Crops, F. Engineering.
Springport	33	57	20	1st	F. Crops, Dairying, Insect Pests.
Three Oaks	22	44	16	1st	F. Crops, Dairying, F. Engineering.
Three Rivers	20	56	17	2nd	F. Engineer., Soils, Hort., F. Management.
Totals	1,073	2,051	711		

ONE-WEEK HOME ECONOMICS EXTENSION SCHOOLS IN 1915-16.

	Average attendance.	Total No. enrolled.	Lectures and demonstrations given.	Subjects given.
Addison	20	43	10	Second year.
Athens	30	40	12	First year.
Battle Creek	24	36	11	First year.
Bangor	23	54	10	Second year.
Berlin	14	20	8	First year.
Bruce Crossing	8	24	7	First year.
Caledonia	13	24	9	Second year.
Caro-Ellington	12	14	8	First year.
Charlotte	33	48	12	First year.
China (St. Clair)	23	31	11	First year.
Chocolay	19	27	6	First year.
Constantine	51	66	11	First year.
Coldwater	31	54	6	First year.
Davis	19	22	4	First year.
Escanaba	23	54	6	First year.
Flushing	37	50	9	First year.
Grand Haven	52	67	9	First year.
Hartford	88	116	11	First year.
Hopkins	41	52	12	First year.
Hudson	25	38	8	Second year.
Jasper-Ridgeville	23	30	10	Second year.
Lake Linden	68	152	11	First year.
Marquette	67	105	6	First year.
Manistique	21	30	6	First year.
Mendon	60	102	11	First year.
Portland	57	82	22	First year.
Plymouth	50	94	10	First year.
Quincy	10	25	5	Second year.
Ray Center	16	17	8	First year.
Scotts	38	44	12	First year.
Total	996	1,561	281	

REPORT OF JUNIOR EXTENSION WORK.

BY E. C. LINDEMANN.

The emphasis in Boys' and Girls' Club work during the past year has been placed on the problem of securing resident leadership. It has been the plan to strengthen the organized communites rather than extend the work to new territory.

There are now 374 organized clubs in the State with a total membership of 5,952. The enrollment for 1915 was 4,290, which indicates an increase of 1,662.

The following club members won State championships in the various projects during the past year:

Howard LaFrance—Potato-growing—Osceola County.
Charles Morrice, Corn-growing—Clinton County.
Johanna Held, Housekeeping—Kent County.
Niles Hagelshaw, Poultry-raising—Calhoun County.

Lenna Morgan, Garment-making—Calhoun County.
Alverta Reagle, Gardening and Canning—Calhoun County.
Helen Denning, Canning—Hillsdale County.
Magnus Nepstad, Gardening—Muskegon County.
Martha Pawloski, Bean-growing—Huron.

The total income for all projects calculated on the basis of those who turned in complete reports was $12,031.28.

The demand for this type of work is increasing in all sections of the State. During the past year it has become necessary to secure additional workers. Miss Anna Bryant Cowles was transferred from the Department of Home Economics Extension to Boys' and Girls' Club work in May, 1916. Chester A. Spaulding was employed as Assistant State Club Leader on July 1st, 1916. Miss Mabel Claire Rogers assisted in the promotion of canning and garment-making clubs during the months of May and June.

The following men have been employed for the purpose of supervising boys' and girls' club work in their respective communities during the summer months:

J. F. Machotka, Kent County.
G. V. Edmonds, Osceola County.
C. E. Ackley, Calhoun County.
R. N. Kebler, Barry County.
R. A. Turner, Hillsdale County.
E. J. Smith, Lenawee County.
J. H. Rayle, Kalkaska County.
Leon Grubaugh, Clinton County.
L. D. Hard*, Manistee County.
K. K. Vining*, Newaygo County.
G. R. Garlock*, Saginaw County.
B. J. Holcomb*, Charlevoix County.

In addition to the regular field work in connection with boys' and girls' clubs there have been conducted the following activities:

Activity.	Place.	Duration.	Attendance. (av.)
School of Instruction for Club Leaders	M. A. C.	6 days	102
School of Instruction for Club Leaders	Mt. Pleasant	3 days	165
School of Instruction for Club Leaders	Kalamazoo	2 days	80
School of Instruction for Club Leaders	Ypsilanti	1 day	175
Club Boys' Camp	M. A. C.	10 days	26
County Round-up for Boys and Girls	Kent	1 day	65
County Round-up for Boys and Girls	Calhoun	2 days	80
County Round-up for Boys and Girls	Mecosta	2 days	70
County Round-up for Boys and Girls	Newaygo	1 day	35
County Round-up for Boys and Girls	Kalkaska	2 days	40
County Round-up for Boys and Girls	Huron	1 day	40
County Round-up for Boys and Girls	Isabella	1 day	50
County Round-up for Boys and Girls	Gladwin	1 day	20
County Round-up for Boys and Girls	Genesee	1 day	65
County Round-up for Boys and Girls	Allegan	1 day	40

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*Those persons whose names are followed by an asterisk are paid wholly by their communities. All others receive a portion of their salaries from the College.

The approximate figures for attendance given in this table for county round-ups indicates attendance of boys' and girls' club members only. Adults, who in most cases greatly exceed the children in number were not included.

The plans for this work for the future include the following:

1. Two new projects to be started in the fall of 1916. One is to be a handicraft project and the other a cow-testing project.
2. Extension of the work to the Upper Peninsula where only four counties have been organized up to date.
3. The development of volunteer resident leaders who will assist school teachers in supervising the work.
4. The employment of county club leaders to be paid in part by the College but eventually by the county itself. This has become a necessary plan of the future for the reason that the county school commissioners and the county agriculturists do not have the time to adequately supervise a county that is completely organized. Whether these county supervisors shall be assistants to the school commissioner or to the county agriculturist is a problem which must soon be solved.

From all viewpoints boys' and girls' club work seems to be progressing as rapidly as is consistent with the development of sentiment and leadership.

REPORT OF EXTENSION WORK IN FARM CROPS.

BY J. W. NICOLSON AND I. K. MAYSTEAD.

With the addition of another man, making two in the Farm Crops Extension work, it has been possible to keep up in a measure with the additional demands being made for this work. Most of the old members of the Michigan Experiment Association have continued their cooperative crop tests and pedigreed seed work and an additional number of State members and local clubs have affiliated with the association. There is a present membership of 1,589,—227 of whom are state members, and 1,362 are distributed among 84 local clubs.

Practically all the members are trying out a cooperative test with an improved grain and some have more than one experiment. Thus, the 1,589 members are trying out a total of 1,777 experiments as follows:

108 tested a bushel of wheat each.
66 tested a bushel of rye.
178 tested a bushel of winter barley.
18 tested a bushel of spring barley.
753 tested a bushel of oats.
439 one or two three-quart samples of corn.
142 two-quart samples of beans.
39 two-quart samples of soy beans.
11 two-quart samples of cow peas.

29 small samples of alfalfa, vetch, etc.
4 fertilizers.

A further idea of the demand for pedigreed seed during the past year may be gained from the following data, which represents the orders received by the Secretary of the Association, Prof. V. M. Shoesmith, and were referred by him to the growers:

475 ordered oats for a total of 4,573 bushels.
13 ordered spring barley for a total of 104 bushels.
84 ordered wheat for a total of 1,279 bushels.
67 ordered rye for a total of 549 bushels.

These figures do not include orders for thousands of bushels received and filled by the grower direct.

SUMMARY.

Extension schools conducted during the year	20	
Public meetings	75	attendance 4,424
Demonstrations	24	attendance 389
Farms visited		505

REPORT OF EXTENSION WORK IN LIVE STOCK.

BY J. A. WALDRON.

The Live Stock Project was the first extension project to be started in Michigan. In September, 1906, the Experiment Station published a bulletin entitled "A Plan for the Improvement of Michigan Cattle" by Dean R. S. Shaw, which was in part a preliminary report of animal breeding experiments then in progress, and in part a statement of the live stock situation in the State and plans for its improvement. A plan for cooperative breeders' associations, known as the block system, was later developed, and Mr. W. F. Raven was appointed as field representative to put it into operation, in December, 1907. Over one hundred breeders' associations of various types have been organized since the work was inaugurated.

Previous to July 1, 1914, the work was supported by College funds and was under the supervision and direction of Dean R. S. Shaw. July 1, 1914, this work because of its nature became a distinct project of the Extension Division of the Michigan Agricultural College and the United States Department of Agriculture, cooperating under the supervision of Director R. J. Baldwin. In Jan., 1916, Mr. W. F. Raven was appointed leader of the project with the title of Extension Specialist in Live stock. March 1, 1916, Mr. J. A. Waldron was appointed to aid in the carrying out of this project with the title of Assistant in Dairy Extension. The object of the project was to aid in the improvement and development of the live stock interests in the State.

The plan of the work was to help in the formation of "cooperative breeders' associations" and "cooperative cow testing associations" in regions requesting aid, and which seemed suited to the development of such organizations; to advise with individuals where requested; to give instruction in extension schools; and to encourage the formation of district and county breed associations.

The following is a list of the Cooperative Breeders' Associations in Michigan, July 1, 1916:

Fairview Guernsey Association.
Climax Guernsey Association.
Long Rapids Guernsey Association.
Richland Guernsey Association.
Blissfield Guernsey Association.
Berlamont Guernsey Association.
Onaway Guernsey Association.
Iron River Guernsey Association.
Leer Guernsey Association.
Dickinson County Holstein Association.
Ray Holstein Breeders' Association.
Standard Holstein Association.
Kent City Holstein Association.
North Hart Holstein Breeders' Association.
Breckenridge Holstein Breeders' Association.
Weare Holstein Association.
Bercula Holstein Breeders' Association.
Menominee Holstein Breeders' Association.
Ontonagon Holstein Breeders' Association.
Ewen Holstein Breeders' Association.
Eau Claire Holstein Breeders' Association.
Shelby Jersey Breeders' Association.
Grand Traverse Jersey Association.
Barryton Jersey Breeders' Association.
Jones Jersey Breeders' Association.
Atlas Jersey Breeders' Association.
Litchfield Jersey Breeders' Association.
Union Jersey Breeders' Association.
Menominee Jersey Breeders' Association.
Lucas Shorthorn Cattle Breeders' Association.
Presque Isle County Live Stock Improved Association.
Southwestern Barry County Dairy Shorthorn Association.
Harrisville Brown Swiss Breeders' Association.

The following is a list of the district or county breed associations in Michigan recorded July 1, 1916:

Fremont Guernsey Association.
Grosse Isle Guernsey Association.
The Metropolitan Guernsey Breeders' Association.
Isabella County Holstein-Friesian Association.

Lenawee County Holstein Association.
Livingston County Holstein Association.
Hudson Holstein Breeders' Association.
Mason County Holstein-Friesian Association.
Central Michigan Holstein Breeders' Association.
Barry County Holstein-Friesian Association.
Saginaw Valley Holstein-Friesian Breeders' Association.
Grand Traverse Holstein-Friesian Association.
Pontiac and Eastern Michigan Holstein Breeders' Association.
Genesee County Holstein-Friesian Association.
Shiawassee County Holstein-Friesian Association.
Berrien County Holstein-Friesian Association.
Northeastern Michigan Holstein-Friesian Association.
Presque Isle County Holstein-Friesian Association.
Columbia Jersey Breeders' Association.
Branch County Jersey Breeders' Association.
Central Michigan Shorthorn Breeders' Association.
Grand Traverse Berkshire Breeders' Association.
Richland Berkshire Breeders' Association.

The work since March 1, 1916, has consisted in giving aid to cow testing associations already in operation in the State; in helping to form new cow testing associations; in getting the history of some of the old cooperative breeders' associations; and in assisting in the organization of new breeders' associations.

Eight of the old cooperative breeders' associations were visited and the history of each organization obtained. Four of these were still in active operation; the other four were broken up because of unavoidable circumstances or having outlived their usefulness.

In communities where the associations were in operation, marked good effects were noted. Without exception the cattle possessed more uniformity as to breed and type. In the case of dairy cows the owners were unanimous in declaring that the progeny of the association bulls were better producers than the foundation stock. Many members of the associations were found who were breeding pure-bred cattle because of the incentive and opportunity furnished them by the cooperative breeders' association. Men not belonging to the associations were found who had begun breeding pure-bred cattle of the same breed to which the association bulls belonged; thus community breeding was promoted.

In all communities where the associations were defunct, marked good effects were noted. Nearly all of the original members were still breeding cattle of the same breed from which the association bulls had been selected, some having purchased better bulls than those owned by the association. The fear of the spread of contagious abortion, the natural distrust of one another, poor business management, and the lack of cooperative spirit, were the usual causes for disbandment of these associations. One successful association had ceased operations because many of the members had died or sold their farms.

The following Cooperative Cow Testing Associations were in operation previous to January 1, 1916:

1. Newaygo County Cooperative Cow Testing Association.
2. Grand Rapids Cooperative Cow Testing Association.
3. Allegan County Cooperative Cow Testing Association, No. 1.
4. Allegan County Cooperative Cow Testing Association, No. 2.

The following new Cooperative Cow Testing Associations have been organized during the fiscal year:

1. St. Clair County Cooperative Cow Testing Association No. 1.
2. Lenawee County Cooperative Cow Testing Association No. 1.
3. Berrien County Cooperative Cow Testing Association No. 1.
4. Berrien County Cooperative Cow Testing Association No. 2.
5. Kalamazoo County Cooperative Cow Testing Association No. 1.
6. North Ottawa Cooperative Cow Testing Association.

There were in all ten Cooperative Cow Testing Associations in Michigan, July 1, 1916. All of the associations had a full membership and were on a sound financial basis, and with the exception of the one in Lenawee county were in active operation. The Lenawee Association was organized with a man hired and ready to begin work October 1, 1916. There were in these ten associations 250 farmers cooperating with 3,529 cows on test.

REPORT OF EXTENSION WORK IN HORTICULTURE.

BY J. H. CARMODY.

The work of the present Extension Specialist in Horticulture began February 24, 1916. Prior to that time it was conducted by Mr. O. K. White. Since that time an effort has been made to get in touch with the fruit growers of the State through meetings arranged principally by the county agents and local horticultural societies for the purpose of determining the most urgent need of the growers.

For the most part these meetings have consisted largely of orchard demonstrations conducted in the orchard with the idea that they may serve as models for the particular community and for interested fruit growers.

In conducting this work it is the plan of the specialist to work as much as possible through organizations rather than individuals. So far the meetings have been largely held in the counties having county agents or in sections where there already exist local horticultural societies. The agent selects the farm or community where the meeting is to be held and the specialist directs the demonstration. In this way the greatest amount of good can be done for the community. Later on other seasonal demonstrations will be held from time to time so that the effects of the methods advocated may be observed.

The work so far has been necessarily formative. Each community problem has been treated individually. Steps are being taken to work out a definite and detailed plan of procedure so that all fruit organizations throughout the State will be working along similar lines.

In addition to working with communities where the fruit interests are already organized it is the plan of the specialist to work outside the regular fruit belt and stimulate interest in other sections where fruit growing is promising.

The following represents the activities of the specialist since taking up the work:

	Number.	Attendance.
Lectures (groups, associations, etc.)	17	1,085
Demonstrations (pruning, spraying, etc.)	51	658
Farm visits (inspections, etc.)	102	....
Days actually devoted to field work	83	....
Total attendance	....	1,743

REPORT OF EXTENSION WORK WITH POTATOES AND VEGETABLES.

BY C. W. WAID.

Potatoes: The extension work with potatoes consists of an organized and cooperative effort to improve conditions connected with the growing and handling of the potato crop in Michigan. The State Potato Association is being used as a means of organizing the growers. The local organizations formed previous to June 30, 1915, have in most cases been continued and a few new local associations have been formed.

The work during the year has been carried on almost entirely in cooperation with county agents. The large increase in the number of county agents has extended the work to so many counties that the Extension Specialists were obliged to confine their work very largely to those counties. The work can also be done much more efficiently where county agents are employed. The following lines of work are being emphasized:

Standardization of Varieties: One of the vital needs in Michigan is fewer varieties of potatoes. To meet this need the members of local organizations are urged to select and grow one variety in a community. Some of the organizations have taken this step and others will before another season.

Seed Treatment: Many more growers treated their seed potatoes in the spring of 1916 than heretofore as a result of the encouragement they received through this work.

Seed Inspection and Selection: The field inspection work was carried on in 1916 much the same as in 1915 except that the work of the Extension Specialists was confined to one field in each important potato growing community in a county. The county agents, however, extended this inspection work as far as their time would permit. Nearby growers were invited to be present when the Specialists inspected the potatoes. In this way a large number of growers were informed as to this method of seed improvement, and also as to the general plans for the betterment of the potato crop. Emphasis has been placed at these meetings on identification of diseases and methods of control together with hill selection of potatoes for seed purposes.

Publications: The following extension bulletins have been prepared and published during the year:

Bulletin No. 3 Some Seed Potato Questions Answered.
Bulletin No. 4: The Home Vegetable Garden.
Bulletin No. 5: Standardization and Group Classification of Potato Varieties for Michigan.

Other publications have been prepared but not printed.

The Market Growers' Journal has continued as the official organ of the National and State Potato Associations. All members of the State Association receive each issue of the journal, and the members of the affiliated local associations receive the six special potato numbers. This has proven a cheap and efficient way of reaching the association members with information relative to the work.

Meetings: The Michigan State Potato Association held a joint meeting and show with the National Potato Association at Grand Rapids, December 1, 2, 3, 1915. The show and program were excellent. The attendance from outside the State was very good, but Michigan growers did not attend in large numbers. Many more local meetings have been held during the past than the previous year.

Demonstrations: The following demonstrations have been made in some of the counties and in the future this phase of the work will be emphasized:

(1) Hill selection of tubers for seed.
(2) The tuber unit method of seed selection.
(3) Greening or green sprouting of the tubers.
(4) Seed treatment for scab and black scurf (rhizactonia).
(5) Close planting on productive soil to increase yield and reduce the percentage of oversized potatoes.
(6) Spraying with Bordeaux to prevent blight.

Vegetables: A State Vegetable Growers' Association was organized at Grand Rapids, December 4, 1915. The Extension Specialist has attended several meetings of vegetable growers but the work has of necessity, because of limited time, been largely of personal visitation to greenhouses and gardens. Communities in which several greenhouses or gardens, or both, are located, are given most frequent visits. Many men have been helped out of difficulties and the work apparently has been appreciated.

Correspondence: The correspondence in connection with this work has become very heavy. Special provision must be made to take care of this part of the work.

SUMMARY.

	Number.	Attendance.
Meetings attended during the year	64	3,326
Personal visits and inspections	254	....

REPORT OF THE WORK OF EXTENSION SPECIALISTS IN THE UPPER PENINSULA.

BY W. F. RAVEN.

Live Stock: The following live stock breeders' associations were organized during the year 1915-16 and were given assistance in securing desirable sires:

	Membership.	Number sires.
Daggett Holstein Association	50	14
Stephenson Holstein Association	20	4
Lake Superior Guernsey Association	36	5
Republic Guernsey Association	13	3
Metropolitan Guernsey Association	16	3
Total (5)	135	29
Number pure bred sires placed outside of association		42
Total pure bred sires placed during year		71
Demonstrations in cattle judging at various county and township fairs		12

Demonstrations in crops were held at Rexford, Shingleton, Rumley, Marquette and Sidnaw.

During the time from March 27 to April 25th our Extension Specialists conducted a Pure Seed Demonstration Train over the Duluth South Shore & Atlantic, Munising, Marquette & Southeastern, Chicago & Northwestern, and Minneapolis, St. Paul and Sault Ste. Marie Railways, with an attendance of over 8,000, two-thirds of whom were farmers. The object of this form of extension work was to get the farmers to sow well cleaned seed.

This is the second time that such a train has been run for the purpose mentioned. Reports from the demonstration train run in the spring of 1915 were that the clean seed produced from ten to twenty-six more bushels per acre than seed that was not cleaned. This effort will be followed by trying to get the farmer, after he sows only clean seed, to sow pure varieties of all grains.

Following is a list of places visited:

	Attendance.		Attendance.
Rexton	60	Montreal	60
Garnet	75	Bergland	100
Gilchrist	40	Topaz	125
Engadine	175	Ewen	160
Gould City	70	Bruce Crossing	100
White Dale	100	Paynesville	200
Manistique	15	Agate	95
Ensign	125	Trout Creek	125
Cooks Mills	90	Kenton	200
Isabella	85	Sidnaw	75
Rapid River	8	Watton	125
Gladstone	80	Covington	250
Dafter	50	Nisula	150
Kinross	50	Pelkie	250
Rudyard	200	Bellaire	30
Dryburg	60	Chassell	50
Hyde	45	Arnheim	27
Bark River	120	Keweenaw Bay	100
Wilson	75	Baraga	200
Nadeau	125	L'Anse	125
Carney	150	Herman	50
Daggett	300	Michigamme	200
Stephenson	190	Champion	175
Ingalls	100	Clarksburg	65
Wallace	200	McMillan	200
Birch Creek	150		
		Newberry	225
Hermansville	150	Strongs	50
Waucedah	175	Brimley	125
Norway	75	Sault Ste. Marie	30
Iron Mountain	150	Trout Lake	20
Crystal Falls	100	Moran	150
Iron River	60		
		St. Ignace	135
Beechwood	60	Mangum	40
Watersmeet	90	Skandia	75
Marenisco	100	Rumley	75
Wakefield	125	Chatham	155
Bessemer	200	Munising	50
Ironwood	250		

The work of the Potato Specialist and of the county agents on potatoes has been very gratifying. Fully fifty per cent of the growers are attempting to standardize the varieties and at many shipping points not more than three varieties of potatoes are grown.

Farmers' Institutes were held in Marquette, Alger, Chippewa, Delta, Irion, Menominee, Dickinson, Gogebic, Houghton and Ontonagon counties, under the supervision of the Extension Specialists and county agents.

Through the efforts of our extension workers the Cloverland Potato Congress was held in Marquette with a splendid attendance of potato growers from every county in the Upper Peninsula.

Two conferences of the county agents in the Upper Peninsula were held during the year; one at Marquette, July 12-13, 1915; one at Crystal Falls, October 13-14, 1915.

Three counties have organized Farm Bureaus and employed county agents, viz., Ontonagon, Schoolcraft and Menominee, in addition to Iron, Houghton, Gogebic, Marquette, Dickinson and Ontonagon.

SUMMARY.

	No.	Attendance.
Meetings and demonstrations held	138	10,879
Demonstration train	75	8,640
Totals	213	19,519

REPORT OF EXTENSION WORK IN FARM MANAGEMENT DEMONSTRATIONS.

BY C. P. REED.

This branch of the Extension work has been continued along the same lines as last year and has been found extremely helpful to those county agents who have continued the project for two years in one locality.

When an agent desires this work as a part of his year's program, from fifty to one hundred farmers are visited in an area selected as being representative of a large portion of the county. These farmers are visited at their farms, a complete report of their farm business for one year is secured, and they are encouraged to cooperate with the College and the U. S. Department of Agriculture in a study of the economic side of farm business. Each farmer who thus gives his "farm record" is furnished a report which shows him what the farm paid for his year's work. If his labor income is not satisfactory, he is shown by comparison with successful farms in the area what efficiency factors on his farm are below par. The county agent then encourages and assists him in taking the steps to improve his situation which the analysis suggests as being the most needed.

The farmers are also encouraged to make a systematic study of their own business with our assistance and guidance. To this end a simple account book has been devised which is placed in their hands and such personal assistance given them by the county agent as seems to be necessary to insure a complete and reliable record of the year's business. These books have been furnished on request to all county agents, and by this means a much larger number of farmers are reached under competent local leadership than is possible by the field survey method alone as followed last year.

The first year's demonstration has been completed in Branch, Iron, Kent and Wexford counties; the second year's demonstration has been completed in Alpena and Newaygo counties, and is now in progress in Branch and Saginaw counties. In addition to the field meetings held in the areas where the work is in progress a number of Farm Bureau meetings have been addressed in other counties and also a limited amount of instruction has been given to short course students at the College. In all cases where the purposes and methods of work have been presented at meetings of County Farm Bureau a unanimous vote in favor of the work has passed with the understanding that it be started in the county at as early a date as possible. More counties are now on the waiting list than it seems possible to assist in the coming year.

The following table gives a summary of the past years' work:

County.	Records taken.		Records returned.		Meetings held.	Attendance.	Farmers using account books.
	1st yr.	2d yr.	By letter.	In person.			
Alpena..........	....	50	....	50	5	145	77
Branch..........	....	60	....	62	6	50	40
Iron............	88	....	22	66	8	75	20
Kent............	....	....	60	14	2	70	61
Newaygo.........	....	100	65	35	5	130	108
Saginaw.........	....	74	....	76	6	180	124
Wexford.........	....	....	150	....	2	40	88
Other counties...	....	....	....	....	4	160	452
Totals......	88	284	297	303	38	850	970

REPORT OF EXTENSION WORK IN ENTOMOLOGY.

BY DON B. WHELAN.

The Extension Specialist in Entomology divides his work between the Extension work and the College. During the past year sixty per cent of the time has been given to the Extension work. The work done may be divided as follows:

(1) Advice and aid in combating insect pests with demonstrations for their control. Most of the work was confined to the southern half of the Lower Peninsula. The work done was in response to requests asking for aid and for advice. Visits were made to 123 farms and homes, demonstrations being held in about half of them. Probably the most serious outbreak was that of the bean-maggot which occurred during the first part of July. This outbreak was worst in Huron, Tuscola, Sanilac, Saginaw, Gratiot, and Eaton counties. The latter part of July was occupied in work on the Hessian Fly which seemed to be worst in the southern part of the State. The white grub was also a very serious pest in some parts of the State. The specialist confined some of his time to the subject of mill and stored-grain insects. He hopes to do still more along this line in the future.

(2) Visiting and aiding the County Agricultural Agents. A point

was made to visit and aid as many of the county agents as possible. The help took the form of demonstrations for insect control or looking up reported outbreaks of some pest.

(3) Lecturing at Extension Schools. Sixteen lectures were given at various schools with an average attendance of twenty-nine. The following lectures were given: "Garden Insects and Their Control," "Fruit Insects and Their Control," "Farm Crop Insects and Their Control," and "Insects Affecting Domestic Animals and Methods of Control." The farmers appeared to be very much interested in these subjects as little has been given along this line heretofore. The lecture on "Garden and Field Crop Insects" seemed to be the most in demand.

(44) Lectures at granges and other meetings. A lecture was given before the Fairfield Grange, Ridgeville, and one before the Farmers' Club at South Riley. Also an illustrated lecture was given before the Detroit Market Growers' Association. All of these were of a general nature on their regular program.

(5) Attendance at State and County Fairs. At the West Michigan State Fair the Extension Specialist was in charge of the exhibits from the Departments of Entomology and Botany. The Entomology exhibit was composed of mounts of various insects of economic importance showing the various stages of the insect and its work. The nature of the work, time of its appearance and control measures were explained to visitors.

At the Van Buren County Fair and the Benton Harbor Fruit Festival the Specialist in Entomology had charge of the entire College exhibit.

REPORT OF EXTENSION WORK IN HOUSEHOLD ENGINEERING.

BY O. E. ROBEY.

Active work on this project was started May 1, 1915. It has been the aim during the past year to determine just what is most needed in the home and how these needs can be supplied.

The object of this work is to encourage better household conveniences in the farm homes of Michigan, especially water and sewage disposal systems.

An effort has been made to find out the actual conditions existing in the farm homes of Michigan with regard to water supply and sewage disposal conveniences. While no accurate data has been collected it would seem from general observation that ninety per cent of the farm homes still lack adequate conveniences, and it is plainly evident that some encouragement should be given to the installation of water supply systems. We find that the majority of homes are supplied with some little mechanical devices for relieving the housewife of petty cares, but a convenient water supply is still the great problem. The reason for this seems to be that the sale of mechanical devices has been pushed by advertising and by agents, while no concerted efforts have been made to sell water systems. In fact in many places it has been found that plumbers are loathe to get out into the country and do the work.

The work has been conducted largely in cooperation with county agents. It has, however, been carried on in a number of counties that do not employ a county agent. This Extension work has consisted of—

1. Demonstrations.
2. Personal assistance.
3. Advice.
4. General plans.
5. Special plans.
6. One-week schools and lectures.

Demonstrations: Demonstrations have been held in eleven counties, viz., Barry, Ingham, St. Clair, St. Joseph, Sanilac, Huron, Clinton, Eaton, Shiawassee, Emmet and Allegan. These demonstrations consisted of giving assistance in the construction of water and sewage disposal systems suitable for the individual farmer's needs. The aim has been to establish these demonstrational outfits in various parts of the counties so that they can be pointed out by the county agents as examples for that particular section. At some of the demonstrations, neighborhood meetings have been held; at others the neighborhood has been informed that the work was going on, and have come individually to see it. It has been found that the effects of a demonstration may not be felt at once in the neighborhood. In the one or two instances where outfits have been established over a year we have found that there has since been a number of similar systems installed.

Personal Assistance. Personal assistance has been given in many cases where farmers wish to undertake the work themselves.

Advice. Advice has been given to a large number of people upon the possibilities of an installation, or upon the selection of proper equipment, and such information has been very well received. Advice has also been supplied by letter to a large number of people. To assist in supplying this information two bulletins have been prepared—one on "Plumbing Suggestions," one on "Septic Tank Construction," and a third on "Water Supply Systems" is under preparation. The early publication of these bulletins would greatly assist in the work.

General Plans. During the spring and autumn months there has been a large number of requests for septic tank plans. A general plan has been prepared to meet this demand.

Special Plans. Many requests have been received for special plans on arrangement of water supply apparatus, plumbing fixtures, kitchen arrangement, etc. An endeavor has been made to supply these plans whenever it seemed practical to do so direct from this office followed by an explanatory letter giving the information in detail.

One-Week Schools. From December 13, 1915, until February 25, 1916, the work was carried on by means of demonstrational lectures at the one-week schools. Four lectures were given at each school, the aim being to cover two schools a week. This same line of work was continued through the "Round-up" at the College. During this time 18 schools were attended and about 1,300 people were present at the lectures. Lectures were given before granges and farmers' clubs whenever there was an opportunity.

SUMMARY.

Demonstrations held	30
Counties in which demonstrations were held	11
Meetings addressed	48
People in attendance	1552
Plans furnished	384
Farms visited	101
Advice furnished	156

Recommendations. Judging from observation, the lack of conveniences in the homes is not due to the farmers' opposition to them, but because either he does not know that such things are possible, or because he has not had these advantages forcefully brought to his attention. It is not always a question of money. A man who can afford an automobile can well afford a water system—even an elaborate one. Yet we find the automobile has been bought many times before the water system, merely because the manufacturer has created the desire through his salesmanship or advertising.

It would seem that one of the greatest needs is more publicity. An attempt should be made to create a desire for more convenient homes and at the same time to disseminate as much information as possible on methods of securing them.

REPORT OF THE MICHIGAN DIRECTOR OF MARKETS.

BY JAMES N. MC BRIDE.

This work under the statute dates from November 1st, 1915. Prior to this time service was rendered in a preliminary way under the immediate direction of the Extension division, with intermittent employment in connection with the organization of the Michigan Bean Growers.

The cordial cooperation of the elevator operators and bean growers has demonstrated the interrelation of production and distribution.

The Michigan bean market was started for the crop of 1915 on a much higher basis than in most of the other states and on an economic food value basis that in price approximated the relation of the crop to the demand. Growers are now fully advised of the size of the crop and the general demand. Conservative marketing instead of dumping at the time of threshing has been made a practice. The Federal Bureau of Markets has complimented this office on these established relations in the distribution of the bean crop. The actual gain to the grower can best be estimated by the increased starting price of fifty cents per bushel for Michigan beans, as compared with that in states where no organization existed.

The Michigan Milk Producers' Association was formed at the College, May 23d, as a direct result of this department's activity. The organization was formed at a meeting attended by nearly 500 milk producers from 44 dairy centers of southern Michigan. One hundred producers became charter members and contributed $500 to the organization fund. Since the initial meeting this department has had frequent conferences with the officers of the state association and has helped to elaborate plans for putting a field secretary at work and for organizing locals in all milk producing sections, after plans proposed by the Federal Office of Markets, and rural organizations.

Early in the crop season of 1916 the fruit growers in the Michigan grape belt called upon this department for aid in forming a federation which would reduce the amount of competition among local marketing associations. Five conferences have been held and a general program elaborated which, it is believed, will result in a strong central organization that will direct grape marketing so that both producer and consumer will profit.

Aid has been rendered the live stock shippers of the State by laying before transportation officials and members of the State Railroad Commission, vital facts bearing upon the handling and shipping of Michigan live stock. Conditions at the Michigan Central yards have been improved.

Grading rules and regulations from different parts of the country and for different products have been collected, that the information may be at hand, and can be used as a basis for the standardization of Michigan farm crops. A tentative set of rules for peaches has been prepared and is the subject of conferences with the peach growers of the State.

Under the statute 74 agricultural meetings and conferences of those interested in cooperating market organizations have been attended.

Five formal bulletins have been issued. The topics covered in these were:

(1) The Bean Outlook; (2) The Wool Market; and (3) Suggestions for Forming Milk Producers' Associations.

Four circular letters have been mailed to producers; and seven newsletters to the newspapers of the State; and more than a thousand personal letters have been written.

Mailing lists for the different projects taken up have been compiled, and other lists for projects soon to be taken on, are under way.

Beginning May 1, 1916, the appointment of Mr. R. H. Elsworth was made, as Assistant to the Director of Markets. His experience in publicity matters and services in cooperative marketing are valuable to the office.

That the Federal Office of Markets is recommending the general plan of the Michigan statute in state and federal agencies of agriculture, is a strong approval of the plan of the legislative act creating this office.

The total expense of the office of the Director of Markets for the past fiscal year was $2,521.84. The items making up the amount are:

Salaries	$1,773 00
Labor	2 63
Publications	10 25
Stationery and small printing	36 43
Postage	64 92
Freight and expenses	89
Furniture and fixtures	65 94
Traveling expenses	567 78

The projects undertaken for the year 1916-17 are as follows:

(1) Outline, in cooperation with the Federal Office of Markets, articles of association and by-laws for standard cooperative marketing associations, and urge existing associations to change their form of organization so as to conform to the standards.

(2) Promote cooperative associations in those communities where such organizations can render economic service.

(3) Bring about the federation of associations marketing similar products.

(4) Aid in the organization of local milk producers' associations which shall become subsidiary to the state association.

(5) Work out the details for the standardization of Michigan farm crops and get uniform standards as to grades into common use either by means of an inspection system or by legislation, or by both.

(6) Work out the details for uniform systems of accounting for the different types of associations and take steps directed toward securing the adoption by the local associations of such systems; devise a workable plan for the auditing of the accounts of the local associations.

(7) Suggest and outline campaigns for the advertisement of seed potatoes, peaches, northern grown cherries, quality apples, and such other products as lend themselves to advertising and can be advertised at a profit.

(8) Promote direct marketing where there is probability of its proving a financial success.

REPORT OF SUPERINTENDENT OF FARMERS' INSTITUTES.

BY L. R. TAFT.

In accordance with the requirements of the law under which the Agricultural College conducts its farmers' institutes, county institutes were held in all counties in which they were requested by the officers of the county institute societies. This included all counties in the Lower Peninsula, and ten counties in the Upper Peninsula, making seventy-eight counties in which institutes were held. In addition to this, the same ten counties in the Upper Peninsula, and all but four in the Lower Peninsula were provided with speakers for a number of one-day institutes. While in a few counties only one to five institutes were held, in many it ranged from five to ten, and in others the number was from fifteen to nineteen.

The same general plan of arranging and planning the institutes was followed as in previous years, the local arrangements and the advertising of the institutes being left with the officers of the county institute societies with a local manager at each point. In counties having county farm agents, they acted as general managers in perfecting the arrangements for the institutes. In the Upper Peninsula, the general arrangements were looked after by Mr. W. F. Raven, who was in charge of the College Extension work in that part of the State.

Several of the regular force of institute lecturers having taken up work as county agents, or in other lines which prevented their giving much time to farmers' institutes, it became necessary to make numerous additions to the corps of institute lecturers, and we were fortunate in securing a number who did excellent work.

In counties having county agents arrangements were made to furnish one state speaker in addition to the county agent, and a series of exchanges were arranged by which the county agents would spend a number of days at institutes in other counties. This aided materially not only in reducing the cost of the institutes, thus making it possible to increase the number that could be held, but it secured as lecturers a number of men who had been upon the force for several years, and others whose observations in the field, in connection with the cooperative work carried on by them during the year, afforded them a store of practical information which they were able to use to the very best advantage at the institutes attended by them.

In the past the benefits derived from the institutes have been lessened by the fact that however strong an impression may have been made by the speakers at the institutes, comparatively few of the farmers present put the suggestions made by the speakers into practice. This objection the county agent can overcome as he will be able to inaugurate a system of "follow up" work. Not only can he induce one or more farmers in each locality to carry on a series of soil, crop or live-stock demonstrations, but by working with and aiding them he will be able to see that they are carried on under proper conditions. The institutes will also provide for county agents a most excellent opportunity for interesting the farmers in the work he is doing for them, and in cooperative demonstration work in the various localities.

ATTENDANCE AND INTEREST.

Especially during December and January the inclement weather greatly reduced the attendance at the institutes. There were several severe snow and sleet storms, and on a number of days the roads and walks were really unsafe on account of a coating of ice.

During the same period there was much sickness and many deaths which not only kept many from attending the institutes, but when the sickness was in the families of the local managers it prevented them from completing the arrangements for and advertising the institutes.

Despite these drawbacks the attendance at a large proportion of the institutes exceeded that of former years so that the general average is very satisfactory.

The topics which received special attention were: Soil renovation; seed selection; growing alfalfa and other legumes; dairying; fruit culture; poultry raising; stock feeding; and home economics. In many sections where such special crops as potatoes, sugar beets, beans, soy beans, etc., are grown, the culture of these was given a prominent place on the program. Among other topics receiving attention were: Land drainage; using concrete on the farm; commercial fertilizers; and marketing.

An endeavor was made to so arrange the topics that at each session the subjects considered bore a close relation to each other and oftentimes, although the program showed that a half dozen topics were discussed, they were so closely related that they virtually constituted one general topic.

Since the close of the institute season it has been observed in many sections that quite a number of the matters discussed at the institutes have been taken up and put into actual practice by many of those in attendance.

For the evening sessions especial attention was given to topics relating to the home and home grounds; sanitation; community building; rural education; and an explanation of the work of the Agricultural College for farmers. As compared with ten years ago a very marked change is noticeable in the views of farmers throughout the State toward the Agricultural College and its work, and nothing has been more instrumental in bringing this about than farmers' institutes.

In addition to the work done by the regular lecturers and the county agents, representatives of several of the College departments attended from one to ten or more institutes and thus gave the farmers entirely new ideas regarding the practical nature of the instruction furnished by the College faculty to the students and also afforded an opportunity for the College men to learn the needs of the farmers.

As in former years, many of the county commissioners of schools took much interest in the institutes, and either took a place upon the program themselves or furnished a speaker upon some educational topic for the evening session.

THE WOMEN'S CONGRESS.

Owing in a large degree to the demonstrations in domestic science provided for the women's congresses there was a considerable increase in the number of institutes having a women's section, and numerous requests have been received for similar demonstrations at the one-day institutes.

At these meetings, in order to secure uniformity and lessen the danger of repetition the same topics were used for all the meetings. "The Principles and Methods of Vegetable Cookery," was assigned to the State speakers and "Saving Steps and Strength in the Home" was used by the local speakers at most of the institutes. Much interest was shown, many questions were asked, and notes were freely taken.

At a few institutes, by special request, "Home Nursing," or "Household Sanitation" was the topic used.

FARMERS' WEEK.

The first week in March was set aside for Farmers' Week at the Agricultural College.

The courses were on the same lines as in previous years. In cooperation with the State Highway department a Highway School intended particularly for highway commissioners was held for two days, with a good attendance.

The usual Country Life Conference was also held during the week, with several speakers from abroad. The different departments were also assisted by outside lecturers, among whom were Prof. C. G. Williams of the Ohio Experiment Station, who aided the Farm Crops department; Mr. W. H. Card, of Connecticut, who spent the entire week with the Poultry department; Dr. H. J. Wheeler, of Boston, also gave an address upon "Liming the Soil."

In several departments the work very largely took the form of demonstrations and much interest was shown.

The attendance reached about one thousand with even more present at some of the evening sessions. While many came for the entire week a large proportion of those from the vicinity of Lansing, who made up a majority of those in attendance, only came for one or two days.

ACKNOWLEDGMENTS.

Aside from the work done by the regular institute lecture force, College faculty and county agents, speakers were also furnished by several State institutions and commissions.

As usual the State Highway department gave its hearty cooperation, as did the State Historical Society, and the State Board of Health. Secretary John I. Gibson of the Western Michigan Development Bureau gave a very interesting illustrated address at several institutes.

The American Portland Cement Manufacturers, Middle West Soil Improvement Committee, and the Kentucky Tobacco Products Company, also furnished speakers for two weeks each to discuss, "Using Concrete on the Farm;" "Handling the Soil;" and "The Control of Plant Lice," respectively. The topics were presented with the idea of furnishing up-to-date information upon the various subjects, and no attempt was made to directly advertise or take orders for any of the materials represented.

Officers of County Institute Societies, 1916-17.

County.	President.	Address.	Secretary.	Address.
Alcona	John McIntyre	Harrisville	Frank LaChapelle	Harrisville.
Alger	C. A. Gogarn	Munising	Wm. Clark	Wetmore.
Allegan	F. H. Williams	Allegan	C. L. Goodrich	Allegan.
Alpena	C. E. VanWagoner	Alpena, R. 2	W. A. Hall	Leer.
Antrim	Jacob Winters	Kewadin	Mrs. Jacob Winters	Kewadin.
Arenac	Albert Christy	Sterling, R. 1	G. W. Cassidy	Standish.
Baraga	Chas. H. Anderson	L'Anse	J. C. Crebassa	Keweenaw Bay.
Barry	Fred E. Otis	Shultz	R. G. Brumm	Nashville, R. 1.
Bay	John Smith	Munger	Harry Horton	Munger.
Benzie	John B. Betts	Benzonia	Jay Robotham	Beulah.
Berrien	Harry L. Young	Niles	Adolph Knott	Niles.
Branch	Linas Taylor	Reading	Frank Demerest	Coldwater.
Calhoun	Frank Munger	Battle Creek	Ray Cook	Eckford.
Charlevoix	D. E. Ingalls	Charlevoix, R. 1	H. L. Barnum	Ironton.
Cass	R. W. Hain	Cassopolis	Alfred George	Cassopolis.
Cheboygan	D. E. Culver	Wolverine	Frank J. Scott	Wolverine.
Chippewa	Jas. Thompson	Brimley	Ed. H. Wyatt	Rudyard.
Clare				
Clinton	H. C. Oven	Ovid	Jerry H. Hubbard	Ovid.
Crawford	L. B. Merrill	Roscommon	Chas. Corwin	Roscommon, R. 1.
Delta	Geo. Jensen	Bark River	F. L. Baldwin	Escanaba.
Dickinson	U. F. Asselin	Norway	C. V. Ballard	Iron Mountain.
Eaton	W. E. Hale	Eaton Rapids	V. G. Griffith	Charlotte.
Emmet	Adolph Grauel	Harbor Springs	Geo. Cook	Harbor Springs.
Genesee	Collins Boomer	Flint, R. 8	G. Blackington	Flint, R. 5.
Gladwin	A. B. Schlichter	Gladwin	C. E. Waite	Gladwin.
Gogebic	S. S. Curry	Ironwood	Thomas Buttson	Ironwood.
Grand Traverse	J. H. Lyon	Williamsburg	E. O. Ladd	Old Mission.
Gratiot	Frank McLean	St. Louis	J. B. Miller	Ithaca.
Hillsdale	E. C. Shupp	Hillsdale	Dr. A. Z. Nichols	Pittsford.
Houghton	David Leveque	Lake Linden	Sydney Odgers	Laurium.
Huron	John S. Gilbert	Harbor Beach	James Todd	Bad Axe.
Ingham	Victor Sitts	Mason	W. H. Freshour	Mason.
Ionia	Chas. T. Lockwood	Portland	Veryl Tyler	Portland.
Iosco	Wm. Latter	Whittemore, R. 2	J. A. Campbell	Tawas City.
Iron	Charles Rogers	Crystal Falls	Jens P. Peterson	Iron River.
Isabella	E. W. Woodruff	Mt. Pleasant	P. P. Pope	Mt. Pleasant, R. 3.
Jackson	J. A. Wright	Jackson, R. 6	W. W. McLain	Jackson.
Kalamazoo	W. H. Smith	Kalamazoo	Harold Brickman	Kalamazoo.
Kalkaska	F. A. Dowling	Williamsburg	F. E. Jenkins	Kalkaska.
Kent	Wm. Oliver	Grand Rapids, R. 2	C. Hunsberger	Grand Rapids, R. 9.
Lake	A. L. Lee	Chase	Chas. A. Steger	Chase, R. 1.
Lapeer	Geo. H. Force	Attica	G. W. Messer	Almont.
Leelanau	Frank Weiler	Sutton's Bay	Theo. Esch	Sutton's Bay.
Lenawee	Peter R. Roberts	Sand Creek	Fred E. Morse	Jasper.
Livingston	W. O. Richards	Oak Grove	Roy Lannen	Howell.
Mackinac	Herbert Summerby	Allenville	Jas. Erskine	Allenville.
Macomb	Frank L. True	Armada	Will L. Lee	Richmond.
Manistee	A. L. Hopkins	Bear Lake	C. W. Glover	Bear Lake.
Marquette	John Wieland	Marquette	F. H. Vandenboom	Marquette.
Mason	O. G. Prettyman	Scottville, R. 3	C. A. Rinehart	Scottville, R. 1.
Mecosta	Eugene Ladner	Big Rapids, R. 3	G. H. Robison	Big Rapids, R. 3.
Menominee	H. E. Johnke	Stephenson	G. C. Swanson	Stephenson.
Midland	Oscar Inman	Averill	A. E. Lawrence	Coleman.
Missaukee	Geo. McBrian	Manton, R. 5	Sidney M. Stevens	Star City.
Monroe	R. G. Vivian	Monroe	J. B. Winslow	Temperance.
Montcalm	Fred L. Dean	Sheridan	Harvey Mulholland	Stanton.
Montmorency	F. C. Harper	Atlanta	C. A. Rice	Atlanta.
Muskegon	Wm. H. Kline	Fruitport	James W. Howard	Muskegon, R. 5.
Newaygo	W. W. Carter	Frant	J. R. Wallace	Fremont.
Oakland	Frank C. King	Pontiac	Howard A. Green	Walled Lake.
Oceana	J. E. Gamble	Hart	A. J. Adams	Shelby.
Ogemaw	Harry Grow	West Branch	E. E. Mathews	West Branch.
Ontonagon	Gilbert Hull	Bruce Crossing	C. E. Peck	Bruce Crossing.
Osceola	C. E. Duesler	Hersey	Ray Pixley	Hersey.

Officers of County Institute Societies, 1916-17.—Concluded.

County.	President.	Address.	Secretary.	Address.
Oscoda	Chauncey Zook	Mio	M. S. Steiner	Fairview.
Otsego	A. Van Auken	Vanderbilt	Dorr D. Buell	Elmira.
Ottawa	Frank C. Hamtleton	Coopersville	A. I. Fairbanks	Holland, R. 9.
Presque Isle	J. M. Whitsitt	Millersburg	John Inglis	Millersburg.
Roscommon	W. M. Coon	Roscommon	W. A. Benton	Roscommon.
Saginaw	Fred Cornair	Chesaning	J. D. Proper	Chesaning.
St. Clair	James M. Haviland	Richmond	J. J. Norman	Atkins.
St. Joseph	Verne Olney	Mendon	C. L. Harrison	Constantine.
Sanilac	Lester Mitchell	Croswell	Archie J. McLachlin	Argyle.
Schoolcraft	Jas. Clark	Gulliver, R. 1	Robt. Arrowood	Manistique, R. 1.
Shiawassee	Mrs. G. M. Getman	Owosso	E. P. Sherman	Owosso.
Tuscola	W. F. Dowling	Akron	Clarence Donahue	Colling.
Van Buren	Thomas Woodman	Paw Paw	Robert Anderson	Covert.
Washtenaw	A. C. Stein	Ann Arbor	G. W. Preston	Ypsilanti.
Wayne	Geo. Burt	Redford	E. R. Laing	Redford.
Wexford	Frank Harris	Manton	J. V. Harrison	Manton.

County Institutes With Dates and Attendance.

County.	Dates.	Place.	Attendance.							Total.	Average per session.
			First day.			Second day.					
			A.M.	P.M.	Eve.	A.M.	P.M.	Eve.	W. C.		
Alcona	Jan. 7-8	Harrisville	15	45	35	28	51	......	36	210	42
Alger	Mar 24	Wetmore	......	30	30	......	......	......	......	60	30
Allegan	Feb 8-9	Martin	100	275	300	250	295	......	155	1,375	275
Alpena	Jan 6-7	Long Rapids	......	24	35	......	15	......	......	74	25
Antrim	Feb. 3-4	Bellaire	80	80	160	80	130	......	82	612	122
Arenac	Jan. 12-13	Standish	10	75	150	50	75	......	......	360	72
Barry	Feb. 11-12	Hastings	66	125	26	50	150	......	92	509	102
Bay	Feb. 1-2	Munger	15	62	58	25	92	......	30	282	56
Benzie	Jan. 31-Feb. 1	Benzonia	93	200	156	95	176	......	75	795	159
Berrien	Feb. 14-15	Three Oaks	30	125	55	60	125	......	126	521	104
Branch	Feb. 16-17	Coldwater	42	125	43	51	122	......	76	459	92
Cass	Feb. 14-15	Cassopolis	90	200	200	90	300	250	124	1,254	209
Charlevoix	Feb. 4-5	Ironton	45	70	132	140	188	......	44	619	124
Cheboygan	Dec. 13-14	Wolverine	19	55	31	87	90	......	35	317	64
Chippewa	Mar. 16	Rudyard	......	35	42	......	......	......	......	77	39
Clare	Jan. 28-29	Clare	30	70	65	35	60	......	60	320	64
Clinton	Jan. 25-26	Ovid	50	92	250	185	200	......	100	877	175
Crawford	Dec. 10-11	Grayling	......	80	96	36	37	......	28	277	69
Delta	May 3	Fayette	......	100	125	......	......	......	......	225	112
Dickinson	Nov. 26	Iron Mountain	......	37	......	......	......	......	......	37	37
Eaton	Jan. 19-20	Charlotte	90	240	200	150	275	......	......	955	191
Emmet	Dec. 13-14	Petoskey	25	50	......	50	52	......	42	219	55
Genesee	Feb. 10-11	Flint	140	200	118	130	85	......	130	803	161
Gladwin	Jan. 13-14	Gladwin	55	120	180	55	130	180	81	891	133
Gogebic	Mar. 29-30	Ironwood	50	80	80	60	105	......	......	375	75
Grand Traverse	Feb. 2-3	Traverse City	35	100	55	60	50	......	30	330	66
Gratiot	Jan. 26-27	St. Louis	100	325	300	160	400	......	200	1,485	297
Hillsdale	Feb. 18-19	North Adams	65	110	98	63	200	......	100	636	127
Houghton	Apr. 4	Chassell	......	65	......	......	......	......	......	65	65
Huron	Feb. 4-5	Bad Axe	22	350	400	52	345	400	140	....	......
Ingham	Jan. 21-22	Mason	35	68	50	60	90	......	180	483	97
Ionia	Feb. 16-17	Portland	75	175	132	125	165	......	248	920	185
Iosco	Jan. 10-11	Whittemore	20	63	115	46	75	......	86	405	81
Iron	Mar. 18	Iron River	......	16	......	......	......	......	......	16	16
Isabella	Jan. 27-28	Mt. Pleasant	80	365	125	150	350	......	......	1,070	214
Jackson	Feb. 21-22	Jackson	14	39	......	15	51	......	22	141	35
Kalamazoo	Feb. 18-19	Damon Church	75	85	100	60	75	......	46	441	88
Kalkaska	Jan. 27-28	Kalkaska	25	175	300	200	450	300	80	1,530	266
Kent	Feb. 11-12	Grand Rapids	120	165	......	195	245	......	32	757	189
Lake	Dec. 16-17	Bristol	40	58	131	58	102	......	32	421	84
Lapeer	Feb. 10-11	Hadley	......	98	475	138	248	......	110	1,069	267
Leelanau	Feb. 1-2	Sutton's Bay	67	250	300	91	200	120	120	1,028	206
Lenawee	Feb. 23-24	Adrian	90	440	......	800	900	......	625	4,155	692
Lenawee	Feb. 25	Adrian	700	600	......	......	......	......	......	....	......
Livingston	Feb. 25-26	Howell	45	210	165	166	205	......	275	1,066	213
Macomb	Feb. 9-10	Warren	22	215	228	56	195	......	145	861	172
Manistee	Jan. 27-28	Bear Lake	50	450	550	400	550	600	90	3,765	471
Manistee	Jan. 29	Bear Lake	475	600	......	......	......	......	......	....	......
Marquette	Mar. 3	Chocolay	......	31	40	......	......	......	......	71	36
Mason	Jan. 25-26	Ludington	84	110	64	225	245	......	72	800	160
Mecosta	Feb. 10-11	Big Rapids	50	100	650	75	115	......	150	1,140	228
Menominee	Feb. 7	Faithorn	......	48	126	......	......	......	......	174	87
Midland	Jan. 31-Feb. 1	North Bradley	72	60	140	80	90	......	100	542	108
Missaukee	Dec. 17-18	McBain	26	110	70	59	89	......	48	402	80
Monroe	Feb. 23-24	Monroe	52	100	95	65	125	......	51	488	97
Montcalm	Feb. 25-26	Stanton	225	375	215	345	575	......	350	2,085	417
Montmorency	Dec. 9-10	Atlanta	12	87	90	27	120	89	60	485	81

County Institutes with Dates and Attendance.—Concluded.

County.	Dates.	Place.	Attendance.							Total.	Average per session.
			First day.			Second day.					
			A.M.	P.M.	Eve.	A.M.	P.M.	Eve.	W.C.		
Muskegon	Feb. 9-10	Cloverville	50	120	200	75	110	......	......	555	111
Newaygo	Feb. 9-10	White Cloud	55	175	168	165	120	......	130	813	163
Oakland	Feb. 24-25	Pontiac	46	71	120	38	110	......	125	510	102
Oceana	Feb. 7-8	Hart	40	76	120	78	80	......	65	459	92
Ogemaw	Dec. 7-8	West Branch	44	47	51	57	60	......	65	324	65
Ontonagon	Mar. 24	Ontonagon	......	17	18	......	......	......	......	35	18
Osceola	Feb. 8-9	Le Roy	50	135	115	90	100	......	85	575	115
Oscoda	Nov. 16	Fairview	60	80	110	......	......	......	......	250	83
Otsego	Dec. 15	Elmira	50	115	94	......	......	......	......	259	86
Ottawa	Feb. 10-11	Holland	98	161	90	200	300	......	......	850	170
Presque Isle	Jan. 4-5	Millersburg	25	50	125	125	75	......	60	460	92
Roscommon	Dec. 8-9	Roscommon	60	75	150	69	66	......	48	468	94
St. Clair	Feb. 8-9	Port Huron	55	68	50	75	90	......	45	383	77
St. Joseph	Feb. 15-16	Sturgis	20	75	100	25	75	......	84	379	76
Saginaw	Feb. 10-11	Saginaw	79	300	200	87	400	500	300	2,241	280
Saginaw	Feb. 12	Saginaw	125	250	......	......	......	......	......	......	......
Sanilac	Feb. 7-8	Croswell	27	215	180	97	225	......	48	792	158
Shiawassee	Feb. 18-19	Owosso	15	80	25	38	119	......	150	427	85
Tuscola	Feb. 2-3	Caro	47	133	42	81	200	......	100	603	121
Van Buren	Feb. 16-17	Paw Paw	125	175	......	160	183	......	146	789	197
Washtenaw	Feb. 22-23	Ann Arbor	87	100	90	120	155	......	68	620	124
Wayne	Feb. 23-24	Redford	38	182	320	55	260	......	......	855	171
Wexford	Dec. 14-15	Manton	40	60	155	70	110	......	32	467	93
Farmers' Week	Feb. 28-29	Agr'l College	......	300	400	630	870	1,000	500	11,110	654
	Mar. 1-2		715	950	750	740	900	950	400		
	Mar. 3-4		645	710	400	250	......	......	......		

Total number of County Institutes	78
Total number of sessions	357
Total number in attendance	64,907
Average per session	177

One Day Institutes with Dates and Attendance.

County.	State speaker.	Places.	Dates.	County secretary.	Attendance. A. M.	Attendance. P. M.	Attendance. Eve.	Total.	Average per session.
Alger	L. R. Walker	Chatham	Mar. 25			60		60	60
Allegan	Alfred Bentall	Chicora	Jan. 10	C. L. Goodrich		150	195	345	172
		Pullman	Jan. 11		62	170	160	392	131
		Leisure	Jan. 12		40	90	115	245	82
		Glenn	Jan. 13		75	200	200	475	138
	R. D. Bailey	Ganges	Jan. 14		75	175	165	415	138
		Saugatuck	Jan. 15		60	120	120	300	100
		Grafschaap	Jan. 17			70	62	132	66
		Hamilton	Jan. 18		29	76	70	175	58
		Burnips Corners	Jan. 19		12	185		197	99
		Corning	Jan. 20		55	75		130	65
		Hopkins	Jan. 21		59	90	54	213	71
		Dorr	Jan. 22		150	300	225	675	225
		Trowbridge	Jan. 24		90	115	74	279	93
		Plainwell	Jan. 25		80	275		355	178
		Dunningville	Jan. 26		60	110		170	85
Antrim	Alfred Bentall	Mancelona	Dec. 14	F. H. Hemstreet		60	52	112	56
		Alden	Dec. 15			75	15	90	45
		East Port	Dec. 16		20	78	53	151	75
Arenac	J. Brainard Brown	County Line	Feb. 19	J. Rutherford, Local Manager		80	135	215	108
Barry	W. F. Taylor	Woodland	Jan. 3	R. G. Brumm	50	225	240	515	172
		Carleton	Jan. 4		42	125	200	367	122
		Hickory Corners	Jan. 5		24	275	260	559	186
		Banfield	Jan. 6		36	198	147	381	127
		Assyria	Jan. 7		40	140	128	308	103
		Nashville	Jan. 8		63	300	325	688	229
		Cressy	Jan. 10		40	110	123	273	91
		Glass Creek	Jan. 11		50	125	80	255	85

Bay	J. Brainard Brown	Auburn	Feb. 16	Harry Horton	....	27	102	129	64
		Pinconning	Feb. 17		40	162	....	202	101
		Bentley	Feb. 18		....	75	100	175	88
Benzie	E. O. Ladd	Honor	Jan. 6	Jay Robotham	*	36	....	36	36
		Lake Ann	Jan. 7		15	27	55	97	32
		Thompsonville	Jan. 10		40	80	170	290	96
		Frankfort	Jan. 11		62	98	150	310	103
		Inland	Jan. 15		*	33	....	33	33
Berrien	H. J. Lurkins	Baroda	Jan. 17	Harry L. Young	65	200	....	265	133
		Buchanan	Jan. 18		12	40	....	52	26
		Niles	Jan. 19		32	100	....	132	66
		Eau Claire	Jan. 20		100	200	92	392	196
		Sodus	Jan. 21		46	197	58	301	151
		Millburg	Jan. 22		110	315	325	750	250
		Riverside	Jan. 24		105	190	....	295	148
Branch	O. G. Barrett	Algansee	Jan. 3	E. W. Farwell	45	70	70	185	62
		California	Jan. 4		70	168	175	413	138
		Kinderhook	Jan. 6		100	200	263	563	188
		Gilead	Jan. 7		63	96	127	286	95
	J. M. Wendt	Bethel Township	Jan. 18		60	100	100	260	86
		Butler Township	Jan. 19		60	80	90	230	76
	E. N. Ball	Girard	Jan. 20		30	60	45	135	43
		Sherwood	Jan. 21		30	110	75	215	72
		Quincy	Jan. 22		40	100	76	216	72
		Noble Township	Feb. 8		....	40	58	98	49
		North Batavia	Feb. 9		26	50	90	166	55
		Ovid Township	Feb. 10		26	44	57	127	42
Calhoun	W. F. Taylor	Penfield	Jan. 24	F. H. McDermid	46	113	88	247	82
		Leroy	Jan. 25		45	90	115	250	83
		Stanley	Jan. 26		35	105	108	248	83
		Abscota	Jan. 27		....	55	58	113	56
		Clarendon	Jan. 28		55	112	82	249	83
		Eckford	Jan. 29		35	47	....	82	41
		Rice Creek	Jan. 31		29	70	48	147	49
		Partello	Feb. 1		27	66	25	118	39
	W. F. Taylor C. H. Burgess	Urbandale	Feb. 2		85	123	92	300	100

One Day Institutes.—Continued.

County.	State speaker.	Places.	Dates.	County secretary.	Attendance.			Total	Average per session.
					A. M.	P. M.	Eve.		
Cass	H. J. Lurkins	Marcellus	Jan. 10	Alfred George	21	62	....	83	41
		La Grange	Jan. 11		36	52	....	88	44
		Jones	Jan. 12		*	15	21	36	18
		Jones	Jan. 13		*	43	....	70	35
		Union	Jan. 14		38	68	46	152	51
		Adamsville	Jan. 15		48	90	....	138	63
Charlevoix	J. Brainard Brown	Marion Center	Feb. 7	H. L. Barnum	30	71	62	163	54
		Maple Grove	Feb. 8		20	25	....	45	22
		Pine Lake	Feb. 9		20	34	24	78	26
		Deer Lake	Feb. 10		65	98	96	259	86
		Clarion	Feb. 11		30	114	80	224	75
		Springvale	Feb. 12		....	82	90	172	86
Cheboygan	R. D. Bailey	Cheboygan	Dec. 18	Frank Scott	97	150	....	247	123
		Weadock	Dec. 20		48	73	....	121	60
		Tower	Dec. 21		64	104	....	168	84
		Afton	Dec. 22		....	54	60	114	57
		Indian River	Dec. 23		45	125	55	225	75
		Wildwood	Dec. 24		30	47	....	77	36
Chippewa	W. F. Raven	Kinross	Mar. 17	E. H. Wyant	....	46	58	104	52
		Pickford	Mar. 18		....	46	14	60	30
		Upper Hay Lake	Mar. 20		....	51	86	137	68
		Brimley	Mar. 21		....	58	....	58	58
		Larch	Mar. 22		....	69	....	69	69
Clare	Newton Burns	Harrison	Feb. 1	Norris A. Eldon	40	65	75	180	60
		Farwell	Feb. 2		55	155	200	410	136
Clinton	E. T. Hallman	Watertown	Nov. 16	Jerry Hubbard	....	70	....	70	70
	C. B. Cook	Maple Rapids	Feb. 18		65	125	....	190	95
	J. S. McDaniel	Delta Center	Feb. 26		65	75	....	140	70

Delta	E. B. Hill	Bark River	Feb. 17	F. L. Baldwin	....	15	35	50	25
Dickinson	L. R. Walker	Vulcan	Mar. 11	C. V. Ballard	....	4	....	4	4
Eaton	C. B. Cook	Mulliken	Feb. 16	V. G. Griffith	30	80	70	180	60
	W. E. J. Edwards	Dimondale	Feb. 26		....	200	....	200	200
Emmet	Chas. H. Gaskill	Harbor Springs	Dec. 6	Frank Angus	30	55	31	116	39
		Stutsmanville	Dec. 7		33	60	53	146	49
		Good Hart	Dec. 8		21	26	....	47	23
		East Bliss	Dec. 9		50	100	....	150	75
		Alanson	Dec. 10		30	150	165	345	115
		Epsilon	Dec. 11		30	115	....	145	73
Genesee	A. C. Anderson	Flushing	July 1	F. W. Swan	175	200	....	375	188
	C. W. Melick	Atlas	Jan. 10		54	155	140	349	116
		Grand Blanc	Jan. 11		32	180	200	412	137
		Swartz Creek	Jan. 12		*28	85	....	113	56
		Gaines	Jan. 13		*23	40	30	93	31
		Linden	Jan. 14		71	137	....	208	104
		Fenton	Jan. 15		22	46	....	68	34
	N. A. Clapp	Davison	Jan. 17		†38	231	312	581	194
		Otisville	Jan. 18		†27	214	197	438	146
		Genesee	Jan. 19		†21	85	110	214	71
		Mt. Morris	Jan. 20		†	95	59	154	77
		Montrose	Jan. 21		†132	280	220	632	316
		Flushing	Jan. 22		†192	434	210	836	279
	S. C. Robinson	Clio	Feb. 16		145	250	800	1,195	398
	Mrs. E. J. Creyts	Clio	Feb. 17		105	375	465	945	315
	S. C. Robinson	Goodrich	Feb. 24		70	350	375	795	265
		Goodrich	Feb. 25		120	355	....	475	238
	J. W. Nicholson	Flushing	Mar. 9		....	250	....	250	250
Gladwin	R. D. Bailey	Wagarville	Dec. 28	C. D. Waite	10	70	147	227	76
		Sherman	Dec. 29		36	60	102	198	66
		Grout	Dec. 30		25	70	140	235	78
		Dale	Dec. 31		83	175	150	408	136

*Bad storm. †Very cold and icy roads.

One Day Institutes.—Continued.

County.	State speaker.	Places.	Dates.	County Secretary.	Attendance.			Total.	Average per session.
					A. M.	P. M.	Eve.		
Gogebic	L. M. Geismar	Wakefield	Mar. 27	J. F. Kadonsky	35	40	50	125	41
		Bessemer	Mar. 28	Local Manager	25	35	125	185	62
Grand Traverse	J. Brainard Brown	Grant Center	Jan. 24	E. O. Ladd	48	65	....	113	57
		Kingsley	Jan. 25		44	152	275	471	157
		Kingsley	Jan. 26		150	210	....	360	120
		Williamsburg	Jan. 27		17	75	95	187	62
Gratiot	M. A. Cobb A. C. Bandeen	Ashley	Jan. 20	J. B. Miller	150	250	300	700	233
	E. M. Moore	Middleton	Jan. 21		40	150	150	340	113
		Middleton	Jan. 22		50	175	....	225	112
		Ithaca	Jan. 24		50	215	....	265	133
		Sickels	Jan. 25		75	150	....	....	....
	A. B. Cook	Alma	Feb. 24		....	....	....	....	....
	F. A. Spragg	Alma	Apr. 6		50	65	....	115	58
Hillsdale	E. N. Ball	Church's Corners	Jan. 10	E. C. Shupp	48	85	60	193	64
		Pittsford	Jan. 11		33	80	75	188	63
		Cambria Township	Jan. 12		25	92	....	117	58
		Montgomery	Jan. 13		48	196	125	369	123
		Litchfield	Jan. 14		25	200	75	300	100
		Allen	Jan. 15		85	300	250	635	212
Houghton	J. F. Kadonsky	Toivola	Apr. 1	Sydney Odgers	....	85	....	85	85
		Lake Linden	Apr. 3		....	40	....	40	40
Huron	N. A. Clapp	Grant Township	Jan. 4	Clarke Munford	....	55	61	116	23
		Pigeon	Jan. 5		....	126	*	126	126
		Elkton	Jan. 6		....	67	135	202	101
		Verona Mills	Jan. 7		....	110	225	335	168
		Ubly	Jan. 8		....	150	125	275	138
		Harbor Beach	Jan. 10		50	200	200	450	150
		Port Hope	Jan. 11		....	96	171	267	133

Ingham	W. F. Taylor	Locke	Jan. 12	Harry Freshour	*	42	30	82	41
		Holt	Jan. 13		*	40	73	113	56
		Aurelius	Jan. 14		*	40	25	65	33
		Leslie	Jan. 15		*21	70	30	121	40
		Dansville	Jan. 17		*	80	112	192	64
		Dansville	Jan. 18		*25	160	....	185	92
	C. B. Scully Mrs. M. B. Ferrey	Stockbridge	Feb. 7		40	220	160	420	140
Ionia	F. L. Dean	Clarksville	Jan. 17	Chas. Lockwood	50	275	150	475	158
		South Boston	Jan. 18		....	65	....	65	65
		Muir	Jan. 19		....	70	....	70	70
		Orleans	Jan. 20		85	210	125	420	140
		Danby	Jan. 22		35	75	....	110	55
	C. B. Cook L. W. Oviatt Mrs. E. J. Creyts	Ionia	Feb. 23		80	140	200	....	....
		Ionia	Feb. 24		85	345	....	850	170
Iosco	R. D. Bailey	Hale	Nov. 9	J. A. Campbell	....	....	52	52	52
		Sherman Township	Nov. 10		30	95	90	215	72
		Grant Township	Nov. 11		15	42	100	157	52
		Alabaster	Nov. 12		40	65	100	205	68
Iron	R. G. Carr	Crystal Falls	Mar. 14	R. G. Hoopingarner, Local Manager	....	30	....	30	30
		Lindquist District	Mar. 15		....	16	....	16	16
		Mapleton	Mar. 15		....	....	24	24	24
		Stambaugh	Mar. 16		....	27	15	42	21
		Beechwood	Mar. 17		27	31	....	58	29
		Nash District	Mar. 17		....	....	14	14	14
Isabella	W. F. Taylor	Shepherd	Dec. 6	E. W. Woodruff	70	150	174	394	131
		Shepherd	Dec. 7		65	250	....	315	158
		Blanchard	Dec. 8		45	135	462	642	314
		Blanchard	Dec. 9		125	450	....	575	288
		Weidman	Dec. 10		....	350	425	775	388
		Brinton	Dec. 11		....	52	138	190	95
Jackson	C. W. Melick	Parma	Jan. 17	W. W. McLain	50	200	125	375	125
		Concord	Jan. 18		12	100	75	187	62
		Pulaski	Jan. 19		....	100	75	175	88
		Horton	Jan. 20		....	125	125	250	125
		Liberty	Jan. 21		75	150	75	300	100
		Rives	Jan. 22		....	150	75	225	112

*Very cold and icy roads.

One Day Institutes.—Continued.

County.	State speaker.	Places.	Dates.	County secretary.	Attendance.			Total.	Average per session.
					A. M.	P. M.	Eve.		
Jackson—*Con.*	Fred L. Dean	Brooklyn	Feb. 8	W. W. McLain	35	175	225	435	145
		Norvell	Feb. 9		30	85	95	210	70
		Michigan	Feb. 10		35	150	210	395	132
		Waterloo	Feb. 11		70	200	185	455	152
		Henrietta	Feb. 12		75	175	225	475	158
	Chas. B. Cook	Tompkins Center	Feb. 17		....	85	90	175	85
Kalamazoo	R. D. Bailey	West Oshtemo	Nov. 30	E. F. Stoddard	58	78	46	182	61
		Alamo	Dec. 1		38	42	26	106	35
		Cooper	Dec. 2		40	61	73	174	58
		Fulton	Dec. 3		14	123	91	228	76
		Vicksburg	Dec. 4		40	110	....	150	75
		Oshtemo	Dec. 6		44	75	57	176	59
		Galesburg	Dec. 7		27	47	41	115	38
		Galesburg	Dec. 8		40	69	....	109	54
		Ross	Dec. 10		28	61	....	89	44
		Kalamazoo	Dec. 11		24	51	....	75	35
		Comstock	Dec. 13		....	63	68	131	65
		Portage	Dec. 14		24	78	70	172	57
		Schoolcraft	Dec. 15		112	151	163	426	142
		Climax	Dec. 16		21	99	121	241	80
Kalkaska	J. Brainard Brown	Rapid City	Nov. 30	Floyd E. Jenkins	12	80	125	217	72
		Excelsior	Dec. 1		30	115	75	220	73
		Boardman Valley	Dec. 2		50	70	71	191	64
		Valentine Grange	Dec. 3		57	135	....	192	86
		Fife Lake	Dec. 4		35	110	90	235	78
Kent	Alfred Bentall	Peach Grove	Jan. 17	C. Hunziker	70	85	....	155	78
		Sparta	Jan. 18		16	57	....	73	37
		Walker	Jan. 19		35	80	....	115	58
		Lowell	Jan. 20		15	47	....	62	31
		Carlisle	Jan. 22		60	95	....	155	78
		Fisher	Jan. 24		12	23	22	57	19
	H. J. Lurkins	Paris	Jan. 25		....	30	50	80	40
		Whitneyville	Jan. 26		....	32	30	62	31
		Ada	Jan. 27		15	62	....	77	39
		Cedar Springs	Jan. 28		33	110	....	143	72

Kent.—*Con*.	H. J. Lurkins	Caledonia	Jan. 29	C. Hunziker	38	140	....	178	89
		Grattan	Jan. 31		68	125	....	193	97
		Cannonsburg	Feb. 1		28	40	....	68	34
		Rockford	Feb. 2		100	179	....	279	139
		Byron Center	Feb. 3		81	155	....	236	118
		Sand Lake	Feb. 4		34	180	....	214	107
		Alpine	Feb. 5		60	115	....	175	88
Lake	J. Brainard Brown	Chase	Nov. 17	Arthur A. Glenn	126	153	200	479	160
		Baldwin	Nov. 18		....	42	50	92	46
		Sauble	Nov. 19		....	54	63	117	59
		Luther	Nov. 20		....	25	43	68	34
Lapeer	Newton Burns	Lapeer	Jan. 8	Geo. W. Messer	95	225	175	495	165
		Almont	Jan. 11		15	75	100	190	63
		Clifford	Jan. 12		....	....	300	300	300
Leelanau	E. O. Ladd	Empire	Jan. 4	Fred Revold	28	66	60	154	51
Lenawee	C. H. Gaskill	Cadmus	Jan. 17	Fred C. Morse	35	80	150	265	88
		Hudson	Jan. 18		*	35	11	46	23
		Rome	Jan. 19		45	115	150	310	103
		Adrian Township	Jan. 20		50	110	125	285	98
		Fruit Ridge	Jan. 21		53	125	100	278	93
		Blissfield	Jan. 22		58	375	210	643	214
		Rollin	Jan. 24		35	75	50	160	53
		North Rome	Jan. 25		100	125	100	325	108
		Tipton	Jan. 26		35	100	110	245	82
		Tecumseh	Jan. 27		85	150	60	295	98
		Macon	Jan. 28		75	150	175	400	133
		Holloway	Jan. 29		80	210	....	290	145
	N. A. Clapp	Medina	Jan. 31		41	56	67	164	53
		Lime Creek	Feb. 1		76	141	195	412	137
		Morenci	Feb. 2		26	288	600	914	305
	E. N. Ball	Fairfield	Feb. 3		70	185	225	480	160
		Ogden Center	Feb. 4		95	285	400	780	260
		Madison	Feb. 5		30	68	75	173	51
Livingston	Chas. B. Scully	Deerfield Center	Feb. 1	H. J. Aldrich	33	100	110	243	81
		Oak Grove	Feb. 2		....	32	....	32	32
		Hamburg	Feb. 3		....	48	52	100	50
		Pinckney	Feb. 4		....	138	....	138	138
		Gregory	Feb. 5		62	182	226	470	157

*Stormy weather

One Day Institutes.—Continued.

County.	State speaker.	Places.	Dates.	County secretary.	Attendance. A. M.	Attendance. P. M.	Attendance. Eve.	Total.	Average per session.
Macomb	C. W. Melick	Davis	Jan. 31	W. L. Lee	30	86	110	226	75
		Meade	Feb. 1		90	160	125	375	125
		Washington	Feb. 2		45	110	85	240	80
		Fraser	Feb. 3		......	100	......	100	100
		Utica	Feb. 4		100	175	100	375	125
		Armada	Feb. 5		30	130	50	210	70
Manistee	J. B. Brown	Kaleva	Jan. 21	L. D. Connelly	*17	......	34	51	26
		Pomona	Jan. 22		50	75	75	200	67
	H. B. Blandford J. F. Zimmer	Kaleva	Mar. 23		150	375	215	740	247
Marquette	C. V. Ballard	Republic	Mar. 27	F. H. Vandenboom	73	20	40	60	88
		Marquette Township	Mar. 28		......	102	......	175	30
		Sands	Mar. 29		......	48	63	111	56
		Skandee	Mar. 30		......	53	78	131	66
Mason	Fred L. Dean	Logan	Nov. 29	C. A. Rinehart	50	76	100	226	75
		Eden	Nov. 30		10	20	......	30	15
		Custer	Dec. 1		25	250	......	275	138
		Victory	Dec. 2		100	125	......	225	113
		Amber	Dec. 3		25	75	125	225	75
		Freesoil	Dec. 4		20	125	......	145	72
Mecosta	A. C. Bandeen	Barryton	Jan. 17	Guy Robison	24	65	......	89	45
		Remus	Jan. 18		25	65	50	140	47
		Millbrook	Jan. 19		40	125	130	295	98
Menominee	E. B. Hill	Hermansville	Feb. 8	G. C. Swanson	......	45	71	116	58
		Wilson	Feb. 9		......	68	61	129	65
		Daggett	Feb. 10		......	178	142	320	160
		Wallace	Feb. 11		......	40	64	104	52
		Arthur Bay	Feb. 12		......	52	......	52	52

Midland	N. A. Clapp	Smith Crossing	Nov. 30	A. E. Lawrence	....	16	31	47	23
		Laporte	Dec. 1		....	51	85	136	68
		Poseyville	Dec. 2		....	19	80	99	49
		Crane	Dec. 3		....	26	87	113	57
		Homer	Dec. 4		....	82	109	191	96
		Midland	Dec. 6		33	52	39	124	41
		Hope	Dec. 7		12	43	140	195	65
		Averill	Dec. 8		19	56	210	285	95
		Coleman	Dec. 9		21	60	116	197	66
	A. C. Bandeen	Pleasant Valley	Feb. 4		25	200	225	450	150
Missaukee	N. A. Clapp	Shippy	Dec. 10	J. Frank Stevens	....	86	126	212	101
		Morey	Dec. 11		52	88	130	270	90
		Moorestown	Dec. 13		....	102	140	242	121
		Star City	Dec. 14		....	40	31	71	36
	N. A. Clapp	Lake City	Dec. 15		....	12	15	27	14
	C. H. Gaskill	Lake City	Dec. 16		10	21	....	31	16
Monroe	W. F. Taylor	Azalia	Feb. 15	Harley Hill	75	200	176	451	150
		Maybee	Feb. 16		125	264	420	809	269
		Raisinville	Feb. 17		56	83	....	139	69
	W. F. Taylor C. W. Melick Newton Burns Dr. G. W. Dunphy Mrs. Dora H. Stockman	Carleton	Feb. 21		65	125	300	490	163
		Carleton	Feb. 22		72	280	....	352	176
	W. F. Taylor Newton Burns J. N. McBride	Milan	Feb. 25		144	275	255	674	225
		Milan	Feb. 26		154	345	....	499	250
Montcalm	R. D. Bailey	Vestaburg	Jan. 3	E. C. Lowry	70	140	200	410	137
		Edmore	Jan. 4		30	80	30	140	47
		Sidney	Jan. 5		25	150	65	240	80
		Crystal	Jan. 6		....	200	100	300	150
		Butternut	Jan. 7		35	100	75	210	70
		Carson City	Jan. 8		40	200	....	240	120
		Greenville	Jan. 24		60	140	150	350	125
	A. C. Bandeen	Trufant	Jan. 25		25	80	50	155	52
		Howard City	Jan. 26		60	200	250	510	170
		Howard City	Jan. 27		50	125	....	175	88
		Lakeview	Jan. 28		200	350	500	1,050	350
		Lakeview	Jan. 29		850	950	900	2,700	900
		Six Lakes	Jan. 31		140	275	....	415	208

*Stormy weather.

One Day Institutes.—Continued.

County.	State speaker.	Places.	Dates.	County secretary.	Attendance. A. M.	Attendance. P. M.	Attendance. Eve.	Total	Average per session.
Montmorency	I. B. McMurtry	Lewiston	Dec. 7	C. A. Rice	48	155	98	301	100
		Big Rock	Dec. 8		46	95	71	212	71
	S. C. Robinson	Royston	Dec. 11		35	67	155	257	86
Muskegon	A. Bentall	Holton	Jan. 11	James Howard	45	100	60	205	68
		Dalton	Jan. 12		50	105	75	230	77
		Norton	Jan. 13		40	80	75	195	65
		Fruitport	Jan. 14		30	175	225	430	143
		Ravenna	Jan. 15		100	235	175	510	170
Newaygo	Alfred Bentall	Sitka	Jan. 3	J. R. Wallace	15	50	....	65	33
		Brookside	Jan. 4		68	100	....	168	84
		Fremont	Jan. 5		55	120	....	175	88
		Bitely	Jan. 6		45	60	55	160	53
		Troy	Jan. 7		70	135	155	360	120
		Grant	Jan. 8		....	140	125	265	133
	A. C. Bandeen	Newaygo	Jan. 11		25	40	....	65	33
		Ensley	Jan. 12		50	100	130	280	93
		Ensley	Jan. 13		65	110	....	175	88
		Hawkins	Jan. 14		115	125	120	360	120
	C. H. Gaskill	Big Rapids	Feb. 5		65	125	....	190	95
Oakland	W. F. Taylor	West Highland	Feb. 18	Percy Nye	60	82	....	142	71
		Ortonville	Feb. 19		86	280	309	675	225
	E. N. Ball	Wixom	Feb. 22		75	175	135	385	128
Oceana	Fred L. Dean	New Era	Dec. 13	A. J. Adams	....	50	120	170	85
		Cranston	Dec. 14		35	55	....	90	45
		Benona	Dec. 15		40	125	....	165	82
		Blooming Valley	Dec. 16		15	40	....	55	28
		Mears	Dec. 17		50	125	110	285	95
		Walkerville	Dec. 18		60	120	150	330	110
Ogemaw	J. B. Brown	Prescott	Feb. 21	W. A. Crandall	....	....	126	126	126
		Prescott	Feb. 22		59	160	180	399	133

Ontonagon	R. G. Hoppingarner	Trout Creek	Mar. 20	Clyde Peck	78	80	....	158	79
		Paynesville	Mar. 21		....	70	....	70	70
		Maple Grove	Mar. 21		....	....	45	45	45
		Ewen	Mar. 22		....	50	110	160	80
		Rockland	Mar. 23		90	130	....	220	110
Osceola	F. L. Dean	Dighton	Dec. 6	W. H. Thacker	70	225	275	570	190
		Marion	Dec. 7		60	220	300	580	193
		Avondale	Dec. 8		75	145	170	390	130
		Evart	Dec. 9		50	185	200	435	145
		Reed City	Dec. 10		100	190	145	435	145
		Maple Hill	Dec. 11		35	75	80	190	63
Oscoda	R. D. Bailey	Comins	Nov. 15	M. S. Steiner	....	60	100	160	80
		Luzerne	Nov. 17		15	25	58	98	33
Ottawa	W. F. Taylor	Nuncia	Feb. 3	A. I. Fairbanks	22	42	....	64	32
		Georgetown	Feb. 4		19	37	....	56	28
		Jamestown	Feb. 5		38	165	175	378	126
		Zeeland	Feb. 7		300	350	....	650	325
	Chas. B. Cook	Coopersville	Feb. 15		80	140	....	220	110
	L. R. Taft	Olive Center	Mar. 15		125	175	....	300	150
		Conklin	Mar. 16		100	150	....	250	125
Presque Isle	R. D. Bailey	Onaway	Mar. 14	Geo. A. Morris, Local Manager	20	40	56	116	39
	S. C. Robinson	Onaway	Mar. 15		255	310	117	682	227
	R. D. Bailey	Onaway	Mar. 16		125	350	154	629	209
	Mrs. D. H. Stockman	Onaway	Mar. 17	Mathew Heslip, Local Manager	152	247	....	399	199
	R. D. Bailey	Hagensville	Mar. 18		18	51	....	68	34
Roscommon	R. D. Bailey	St. Helens	Nov. 20	Louis C. Myer	50	70	80	200	67
		Houghton Lake	Nov. 22		12	72	78	162	54
Saginaw	Leo C. Reynolds	Chapin	Jan. 12	B. S. Tefft	....	55	60	115	58
	N. A. Clapp	Brant	Jan. 13		....	70	21	91	46
		Freeland	Jan. 14		30	95	90	215	72
		Burt	Jan. 15		....	30	....	30	30
		Hemlock	Jan. 24		35	100	125	260	87
	C. W. Melick	Lawndale	Jan. 25		12	100	....	112	56
		Chesaning	Jan. 26		75	300	75	450	225
		Birch Run	Jan. 27		40	100	....	140	70
		Bridgeport	Jan. 28		25	70	75	170	57
		Frankenmuth	Jan. 29		35	170	....	205	102

One Day Institutes.—Continued.

County.	State speaker.	Places.	Dates.	County Secretary.	Attendance.			Total.	Average per session.
					A. M.	P. M.	Eve.		
St. Clair	J. Brainard Brown	Capac	Jan. 4	John J. Norman	*75	75	95	170	85
		Emmett	Jan. 5		*	50	80	130	65
		Goodells	Jan. 6		*	95	135	230	115
		Adair	Jan. 7		15	110	130	255	85
		Blaine	Jan. 8		....	80	120	200	100
		Starville	Jan. 10		25	110	122	257	86
		Smith Creek	Jan. 11		21	98	162	281	94
		Avoca	Jan. 12		15	75	85	175	58
		Yales	Jan. 13		15	40	....	55	28
St. Joseph	E. N. Ball	Moorespark	Jan. 3	J. M. Wendt	34	79	74	187	62
		Constantine	Jan. 4		20	125	82	227	76
		Three Rivers	Jan. 5		19	56	17	92	31
		Riverside Gr. Hall	Jan. 6		41	82	86	209	70
		White Pigeon	Jan. 7		30	125	80	235	78
		Florence	Jan. 8		....	35	62	97	49
		Burr Oak	Jan. 24		....	75	125	200	100
		Colon	Jan. 25		....	150	175	325	162
		Leonidas	Jan. 26		42	150	125	317	106
	J. W. Chapin	Leonidas	Jan. 27		42	115	125	282	93
		Parkville	Jan. 28		45	108	85	238	79
		Centerville	Jan. 29		42	100	125	267	83
Sanilac	S. C. Robinson	Marlette	Jan. 25	W. J. Musselman	140	200	200	540	180
		Shabbona	Jan. 26		15	100	300	415	138
		Argyle	Jan. 27		25	290	200	515	172
		Snover	Jan. 28		16	175	205	396	132
		Sandusky	Jan. 29		70	205	305	580	193
		Carsonville	Jan. 31		....	29	105	134	67
		Lexington	Feb. 1		....	105	400	505	153
		Brown City	Feb. 3		40	300	220	560	187
		Brown City	Feb. 4		80	350	350	780	260
Shiawassee	J. Brainard Brown	Henderson	Jan. 14	C. T. Cook	20	75	50	145	48
		Bancroft	Jan. 15		50	95	....	145	73
		Morrice	Jan. 18		....	62	85	147	74
		Maple River Church	Jan. 19		35	73	....	108	54
	Mrs. C. L. Barber	Perry	Apr. 11		....	125	....	125	125

Tuscola	Newton Burns	Kingston	Jan. 13	Clarence Donahue	50	200	250	500	167
		Mayville	Jan. 14		50	500	....	550	275
		Fostoria	Jan. 15		100	350	300	750	250
		Reese	Jan. 17		....	100	100	200	100
		Akron	Jan. 18		30	160	150	340	113
		Unionville	Jan. 19		15	150	200	365	122
Van Buren	R. D. Bailey	Kendall	Jan. 10	Robt. Anderson	80	160	....	240	120
		Bloomingdale	Jan. 11		125	125	80	330	110
		Glendale	Jan. 12		30	65	....	95	48
		Lawrence	Jan. 13		25	85	....	110	55
		Hamilton	Jan. 14		35	80	....	115	58
		Keeler	Jan. 15		45	155	....	200	100
	H. B. Blandford	Hartford	Jan. 18		34	78	....	112	56
		Bangor	Jan. 19		30	50	....	80	40
		Covert	Jan. 20		140	150	....	290	145
		Almena	Jan. 21		75	160	75	310	103
	C. H. Burgess	Grand Junction	Jan. 19		40	85	....	125	62
Washtenaw	Fred L. Dean	Salem	Feb. 3	Geo. W. Preston	75	175	125	375	125
		Ypsilanti	Feb. 4		85	275	....	360	180
		Dixboro	Feb. 5		75	165	200	440	147
		Chelsea	Feb. 7		30	300	....	330	165
	W. F. Taylor	North Lake	Feb. 8		....	60	100	160	80
		Northfield	Feb. 9		35	150	175	360	120
		Saline	Feb. 10		70	175	160	405	135
		Willis	Feb. 11		65	250	155	470	157
		Manchester	Feb. 12		....	124	115	239	119
Wayne	Chas. B. Scully F. O. Foster	Northville	Feb. 14	J. C. Pullen	57	110	248	415	138
		Canton	Feb. 15		84	200	175	459	153
		Belleville	Feb. 16		48	126	235	409	136
		Martinsville	Feb. 17		51	137	175	363	121
		New Boston	Feb. 18		20	68	181	269	90
		Flat Rock	Feb. 19		64	178	235	477	159
		Gibralter	Feb. 21		31	70	85	186	62
		Romulus	Feb. 22		59	121	306	486	162
	C. H. Burgess	Detroit	Jan. 21		....	....	107	107	107
		Detroit	Jan. 22		76	103	158	337	112

*Stormy weather.

One Day Institutes.—Concluded.

County.	State speaker.	Places.	Dates.	County secretary.	Attendance.			Total.	Average per session.
					A. M.	P. M.	Eve.		
Wexford	J. Brainard Brown	Hoxieville	Dec. 7	Wm. Bishop, Sr.	100	140	....	245	122
		Boone	Dec. 8		50	110	....	160	80
		Harrietta	Dec. 9		40	175	....	215	108
		Mesick	Dec. 10		150	200	....	350	175
		Buckley	Dec. 11		40	60	....	100	50
		Meanwataka	Dec. 13		80	125	....	205	102
	J. Brainard Brown	Cadillac	Dec. 16		50	75	25	150	50
	Mrs. S. H. Noecker	Cadillac	Dec. 17		75	150	50	275	92

Total number of One-day Institutes	470
Total number of sessions	1,152
Total attendance	114,303
Average per session	91
Grand total attendance	179,210

Dr. F. S. Kedzie, President Michigan Agricultural College:

My Dear Mr. President—I have the honor to present my ninth annual report as Dean of Engineering.

The student enrollment for the year just closed is:

Freshmen	131
Sophomores	88
Juniors	83
Seniors	71
Special and Summer	35
Total	408

The graduating class, 66 in number, is a "record breaker" for engineering at M. A. C., and brings the total of engineering graduates of the institution to 749.

The teaching *personnel* of the Division of Engineering is given in the reports of the several departments and numbers 37 persons, exclusive of student assistants.

I was absent on leave from July 27, 1915 to January 1, 1916, and spent most of the time on the Pacific coast. During my absence Prof. J. A. Polson was Acting Dean of Engineering, and discharged the duties of the position very acceptably.

During the fall term Prof. V. T. Wilson resigned his position as head of the Department of Drawing and Design, effective September 1, 1916.

Mr. Wilson held his position for eight years, and was an efficient officer and teacher and an agreeable colleague.

The vacancy thus created will be filled by Mr. R. K. Steward, who has been appointed, effective September 1, 1916. Mr. Steward comes to M. A. C. from the University of Illinois.

The *organization* of the Division of Engineering will be materially changed by the decision to divide the Department of Physics and Electrical Engineering into a department of Physics, assigned to the Division of Science, and a department of Electrical Engineering, assigned to the Division of Engineering.

The *course of study* has been changed by the addition thereto of a line of options in applied *chemistry*, whereby those students who have predilections for *chemical engineering* may have opportunity to satisfy the same in the junior and senior years to the same extent as those preferring civil engineering work.

This change was made to meet what is believed to be a real demand for technical training for the manufacturing industries based upon chemistry. Already considerable interest is manifested by our students in this new feature of the course.

The course, as a whole, however, is still unique in the emphasis placed upon the idea that a general course in engineering, characterized by thorough work in fundamentals, has a place and meets a real need.

The outstanding event of the year for the whole College, as well as for the division, was the *fire,* which, on March 5, 1916, destroyed the engineering buildings and most of their contents, with the exception of the foundry wing, a loss, based upon inventoried values of $250,000, and a replacement loss of $350,000. These figures do not include the personal losses in books, instruments, data and records of the teaching force of the division, nor the losses of drawing and other tools and clothing by the students.

I was out of the city at the time. The President was on the ground, and to his energy and good judgment, is due the recovery of the students, faculty and community from the immediate shock of the catastrophe and the awakening in all concerned of a magnificent spirit of cooperation around the central idea of restoration of engineering at M. A. C. to its former status and a better foundation than ever before.

Classes, deprived of facilities by the fire, were assembled for work in provisional quarters on the day following the fire, and the work of the winter term was completed in good form.

The President, the College Architect and the Dean of Engineering, at once began the preparation of plans for rebuilding. See Exhibit "A" appended hereto. These were soon completed for submission to the Board of Agriculture, which authorized the calling for bids, and on April 19th contracts were awarded to F. C. Trier of Saginaw for the rebuilding of the Engineering Building as a fire-proof structure on substantially the same lines, as the old building erected in 1907, and to Byers Bros. Construction Company of Kalamazoo for three fire-proof shop buildings, each covering a ground area, 160 x 50 feet, one of them two stories in height, the others one story.

The financial problem involved in the plans for the restoration of engineering was serious, but was relieved in a large measure by the contribution of the sum of $100,000 by Mr. R. E. Olds of Lansing towards the cost of replacing the buildings. This gift resulted from the personal suggestion of the President.

The new engineering hall will be called The R. E. Olds Hall of Engineering as a reminder of the generosity of Mr. Olds, and to perpetuate the significance of the gift as a *recognition* of engineering at M. A. C. by one of the foremost manufacturers and citizens of Michigan.

Parallel with the building plans were the plans for equipment. Surveying instruments to the value of $5,000.00 were ordered immediately for the spring term. Machinery, instruments and furniture have been already largely selected and placed on order.

The ruins have been wrecked and cleared away, ground broken for the new shops, and the walls are going up under the energetic driving of the contractors and the interested eyes of everybody.

It is expected that the shops will be occupied for work at the beginning of the fall term, 1916, and that the R. E. Olds Hall of Engineering will be completed by December 1, 1916.

The next annual report of the Dean of Engineering should contain full descriptions of the new buildings and equipment, and should chronicle the completion of an achievement highly creditable to this College—the successful recovery from a great disaster and its conversion into a new era which will be characterized by greater solidarity of interests between all of the activities of the entire College than ever before, and by the certain knowledge, born of experience, that cooperation, hard work and determination are equal to any emergency.

On behalf of the Division of Engineering, as well as for myself personally, I sincerely thank authorities, colleagues, co-workers, students and our friends everywhere for their sympathetic cooperation in the work of restoration of engineering at M. A. C.

Respectfully submitted,
G. W. BISSELL,
Dean of Engineering.

East Lansing, Mich., June 30, 1916.

EXHIBIT "A".

March 13, 1916.

Dr. F. E. Kedzie, East Lansing, Mich.:

My Dear Mr. President—I have to report that on the morning of Sunday, March 5th, a disastrous fire swept the engineering buildings of the College and destroyed Engineering Hall and all of the shop buildings except the foundry and lumber shed. Some damage was done to the east end of Wells Hall and the Power House, Veterinary Building, old Boiler House and Carpenter Shop were seriously threatened.

The combined efforts of the College and Lansing fire departments prevented damage beyond that above stated.

By the valiant efforts of College authorities, teachers and students, and others, considerable valuable machinery and apparatus were removed from the basement of the west end of Engineering Hall and from the machine shop.

I was in Chicago at the time of the fire, and did not return to the Campus until late in the afternoon. Upon arrival I found that arrangements had been made for taking up, in temporary quarters all of the classes previously accommodated in the engineering buildings.

This was a wonderful achievement, and I wish here to record my sincere thanks and appreciation of the efforts made and results accomplished by President and other authorities, our colleagues in all departments of the College, and by the students. The real M. A. C. spirit conquered every obstacle, and at this writing I can report that all work is going on profitably to all concerned, in spite of inconveniences here and there.

The engineering plant, previous to the fire, had an inventorial valuation of $240,000. Of this amount there is now available the following:

BUILDINGS.

Foundry and equipment	$7,000 00	
Lumber shed and stock	1,000 00	
		$8,000 00

SALVAGE OF EQUIPMENT FROM THE FIRE.

Civil Engineering	$1,200 00	
Drawing and Design	....	
Mechanical Engineering	15,000 00	
Physics and Electrical Eng.	7,000 00	
		$23,200 00
		$31,200 00

The above statement does not include possible salvage of equipment from the ruins of the buildings.

The above statement of values before or after the fire does not include personal losses of students or teachers. The former lost heavily in drawing instruments and the latter in books, instruments and such irreplaceable property as lecture notes, problem material, correspondence, personal professional data, etc.

Expressions of sympathy are pouring in from alumni, from teachers and others personal friends of the College or of those here engaged and from other colleges and universities.

Some of the latter have offered the loan of apparatus and arrangements have already been made to borrow from the University of Michigan and from the University of Illinois.

Plans for the future include instruction for the spring term and the reconstruction of the physical plant.

All instruction work is provided for on lines meeting fully the exigencies of the situation. A complete working schedule of classes with room assignments for the spring term has been completed by the Registrar. Equipment is being ordered for laboratory work, or is being installed from that which was saved from the fire. Students are kept fully informed and are backing us to a man.

My ideas for the reconstruction of the buildings are formulated in a general way and presented graphically on the blue-print of "Greater Engineering at M. A. C." submitted herewith. The central idea is the absolute necessity of haste.

(a) The immediate reconstruction of Engineering Hall as a fire-proof building, on the old foundations, and, consequently, with only minor changes in interior arrangement.

(b) The erection at once of one two-story fire-proof shop building, with frontage on the line of Wells Hall, Engineering Hall and Power House.

(c) The erection of two one-story fire-proof shop buildings parallel to (b) and between it and the Pere Marquette siding.

(d) The erection, as the future may require, of additional one-story fire-proof shop or laboratory units as indicated in the print.

(e) All shop units to cover a ground area 160 x 50 feet.

I have gone into details with the architect, and he is preparing plans and specifications as the basis of bids from contractors.

Operations on all features of the above building plan should be started at once, not only that the Division of Engineering shall again have a plant adequate to its needs, but in order to sustain the *morale* of teachers and students and to demonstrate to the people the recuperative power of the College when misfortune hits at its foundation principles.

Work on the shop units can begin without waiting for the clearing of the ruins, and I strongly urge that no time be lost in breaking ground and raising the walls.

Respectfully submitted,
G. W. BISSELL,
Dean of Engineering.

Dr. F. S. Kedzie, President Michigan Agricultural College:

Dear Sir—This communication constitutes my ninth annual report as professor of mechanical engineering at M. A. C.

I was absent on leave from July 27th to December 31, 1916. During my absence the department was in charge of Associate Professor J. A. Polson, who also acted as Dean of Engineering.

The personnel of the department at the opening of the college year was as follows:

J. A. Polson, Acting Professor,
E. G. Greenman, Assistant Professor,
J. L. Morse, W. E. Stark, L. S. Eaton, E. A. Evans, A. P. Krentel, W. R. Holmes, J. A. Eicher, G. H. Peters, J. D. Smith, and H. Garrison, Instructors.
E. C. Crawford, Laboratory Engineer,
Miss K. Nichols, Clerk.

Changes during the year are here enumerated.

Mr. E. G. Greenman resigned at the end of the fall term. Mr. L. N. Field was appointed in his place.

Mr. H. Garrison died suddenly during the holidays and Mr. C. E. Wood was appointed to the vacancy.

Changes now in sight for the coming year will be made consequent upon the promotion of Mr. J. A. Polson to the rank of Professor of Mechanical Engineering; the resignation of Mr. W. E. Stark to accept a position at the Case School of Applied Science and of Mr. J. D. Smith to accept a commercial position; the refusal of Mr. L. S. Eaton to accept his appointment; the withdrawal of Mr. W. R. Holmes.

The teaching schedule of the department is given in Exhibit "A", appended hereto.

It will be noted that M. E. 18c is not listed as hitherto. This is because the course was given by Professor C. S. Dunford, of the Department of Economics, as an accommodation, in the absence of the undersigned, who appreciates the favor thoroughly.

It will also be noted that M. E. 21b, a course in woodworking for women, was not given in the spring term. Its omission was made necessary by the fire.

Notwithstanding two disturbing influences,—changes in personnel and the fire, the work of the department has been satisfactory and I hereby thank the members of my staff for their cooperation.

The outlook for the future, due to the new shops, new building, and the opportunity of obtaining new equipment, is bright.

The shop work will be reorganized to emphasize, for engineering students, the importance attached, in industrial life, to production and the value of time in obtaining results.

The work in machine design will be administered by the Department of Drawing and Design.

The Department of Mechanical Engineering will be under the direction of Professor J. A. Polson.

Respectfully submitted,
G. W. BISSELL,
Professor of Mechanical Engineering.

East Lansing, Mich., June 30, 1916.

EXHIBIT "A".

TABLE I.

Class Work of Department of Mechanical Engineering, Fall Term 1915.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
Freshman	Woodshop	2a	Mr. Krentel Mr. Peters Mr. Garrison	6	133	798
Freshman	Forge Shop	3a	Mr. Holmes	3	6	282
Sophomores	Forge Shop	3a	Mr. Holmes	3	87	
Juniors	Forge Shop	3a	Mr. Holmes	3	1	
Sophomores	Foundry	4a	Mr. Eicher	3	82	255
Juniors	Foundry	4a	Mr. Eicher	3	1	
Seniors	Foundry	4a	Mr. Eicher	3	2	
Sophomores	Machine	2h-2-1	Mr. Evans, Mr. Smith	6	3	564
Juniors	Machine Shop	2h-2-1	Mr. Evans, Mr. Smith	6	68	
Seniors	Machine Shop	2h-2-1	Mr. Evans, Mr. Smith	6	23	
Freshmen	Machine Design	6a	Mr. Morse, Eaton, Student Assts.	6	1	540
Sophomores	Machine Design	6a	Mr. Morse, Eaton, Student Assts.	6	86	
Juniors	Machine Design	6a	Mr. Morse, Eaton, Student Assts.	6	2	
Special	Machine Design	6a	Mr. Morse, Eaton, Student Assts.	6	1	
Juniors	Machine Design	6c	Prof. Greenman	6	50	300
Seniors	Gas Power Engineering	8c	Prof. Polson	3	39	117
Juniors	Metallurgy	11a	Mr. Morse, Mr. Eaton, Mr. Stark	2	83	166
Seniors	Engine Laboratory	13c	Prof. Polson, Mr. Stark	4	66	264
Seniors	Heating and Ventilating	18a	Prof. Greenman	3	40	120
Total					774	3,406

TABLE II.

Class Work of Department of Mechanical Engineering, Winter Term 1916.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
Freshmen....	Woodshop..............	2b.....	Mr. Krentel.................. Mr. Peters..................... Mr. Wood.....................	6	117	702
Freshmen....	Elements of Engineering..	1......	Prof. Bissell.....................	2	103	206
Freshmen....	Forge Shop.............	3b.....	Mr. Holmes.....................	3	5	234
Sophomores..	Forge Shop.............	3b.....	Mr. Holmes.....................	3	72	
Juniors......	Forge shop.............	3b.....	Mr. Holmes.....................	3	1	
Freshmen....	Foundry...............	4b.....	Mr. Eicher......................	3	1	228
Sophomores..	Foundry...............	4b.....	Mr. Eicher......................	3	73	
Seniors......	Foundry...............	4b.....	Mr. Eicner......................	3	2	
Sophomores..	Kinematics.............	6b.....	Mr. Morse, Eaton, Student Assts...	5	97	545
Juniors......	Kinematics.............	6b.....	Mr. Morse, Eaton, Student Assts...	5	12	
Juniors......	Steam Engine and Boilers.	7a.....	Mr. Morse, Mr. Stark, Mr. Eaton..	3	82	246
Juniors......	Machine Design.........	6d.....	Mr. Morse......................	6	49	294
Juniors......	Engineering Laboratory..	13a....	Prof. Polson, Mr. Stark...........	4	79	316
Sophomores..	Machine Shop..........	2h 2-1..	Mr. Evans, Mr. Smith............	6	2	360
Juniors......	Machine Shop..........	2h 2-1..	Mr. Evans, Mr. Smith............	6	46	
Seniors......	Machine Shop..........	2h 2-1..	Mr. Evans, Mr. Smith............	6	12	
Seniors......	Engineering Laboratory..	13d....	Prof. Polson, Mr. Stark...........	8	39	312
Seniors......	Works Management.....	5a.....	Prof. Polson.....................	3	49	147
Seniors......	Steam Engine Design....	8b.....	Mr. Eaton......................	8	26	208
Seniors......	Power Station Design....	18b....	Prof. Bissell.....................	7	37	259
J'r Women...	Woodwork..............	21a....	Mr. Krentel.....................	4	57	228
Total...	....	....	....	....	961	4,285

TABLE III.

Class Work of Department of Mechanical Engineering, Spring Term 1916.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
Freshmen....	Woodshop..............	2c.....	Mr. Krentel.................. Mr. Peters..................... Mr. Wood.....................	6	96	576
Sophomores..	Forge Shop.............	3c.....	Mr. Holmes.....................	3	87	264
Juniors......	Forge Shop.............	3c.....	Mr. Holmes.....................	3	1	
Freshmen....	Foundry...............	4c.....	Mr. Eicher......................	3	2	216
Sophomores..	Foundry...............	4c.....	Mr. Eicher......................	3	70	
Sophomores..	Machine Shop..........	2h-2-1..	Mr. Evans, Mr. Smith............	6	1	228
Juniors......	Machine Shop..........	2h-2-1..	Mr. Evans, Mr. Smith............	6	37	
Juniors......	Thermodynamics........	17a....	Prof. Polson, Mr. Field, Mr. Eaton	4	75	328
Seniors......	Thermodynamics........	17a....	Prof. Polson, Mr. Field, Mr. Eaton.	4	7	
Juniors	Engineering Laboratory..	13b....	Prof. Polson, Mr. Stark...........	4	76	304
Juniors......	Steam Engine Design.....	8a......	Mr. Field, Mr. Morse.............	4	45	180
Seniors......	Jig Design..............	6e.....	Mr. Field........................	6	23	138
Seniors......	Machine Tool Design....	6f.....	Mr. Field........................	6	1	6
Seniors......	Thesis.................	19a....	Prof. Bissell, Prof. Polson, Mr. Field.	20	27	540
Total...	....	....	....	....	548	2,780

REPORT OF THE DEPARTMENT OF CIVIL ENGINEERING.

President F. S. Kedzie:

Dear Sir—Permit me to hand you herewith a brief record of activities in the Department of Civil Engineering for the year 1915-1916. Despite an unprecedented variety of hindrances there has been an unusual measure of accomplishment, and we are entitled to a corresponding feeling of satisfaction in the results attained. There has been need of industry to carry on the work and the members of the departmental staff have responded willingly and adequately.

I wish to commend emphatically the energy and fidelity with which every one of my assistants met the trying period which followed the disastrous fire of March fifth. Since that date the duties of all of them have easily been doubled while some of the class work has been hampered by numerous obstacles. Though for a short time without any equipment for laboratory work, and throughout the spring term with only a partial provision of the instruments needed for the proper conduct of field practice, the instructors in civil engineering kept the attention and interest of their classes without exception, and the emergency as a whole was attended with a minimum of injury to the students. The latter have shown a particularly wholesome spirit of endeavor as well the teachers, supplementing very nicely the efforts of the faculty and proving conclusively that our students have a seriously thoughtful interest in securing the training in engineering offered at this college.

As of possible interest in connection with the history of the department it is proper to note the utter loss of all department records in the fire. The records of student progress and rank were complete and valuable covering every item of class work that has come under my direction at this college, for a period of twenty-five years. Further, while my own loss of books, instruments and other effects was serious and significant, aggregating hundreds of dollars in value, I regret much more keenly the destruction of thousands of maps, plans, notes, photographs, problems and data for class use which, though my personal property, had been dedicated to the use of students. Much of this matter had been collected from professional practice and can never be replaced.

There was one withdrawal from our department staff between the date of my last report and the beginning of this college year. Two vacancies were filled and the work of the year was shared by the following list of teachers, whose names appear in order of seniority of appointment:

H. K. Vedder, C. E., Professor of Civil Engineering.
C. A. Melick, D. C. E., Assistant Professor of Civil Engineering.
C. M. Cade, C. E., Instructor in Civil Engineering.
R. G. Saxton, C. E., Assistant Professor of Civil Engineering.
W. W. Hitchcock, B. S., Instructor in Civil Engineering.
B. K. Philp, C. E., Instructor in Civil Engineering.
H. I. Davies, B. S., Instructor in Civil Engineering.
H. A. Gehring, C. E., Assistant Professor of Civil Engineering.

Since March 6th the department has occupied temporary quarters provided mainly in the Agricultural Building, with an occasional assignment of classroom space elsewhere about the campus. In the Agricultural Building, a part of room 14 was used for storing our instruments and other equipment besides providing desk space for Assistant Professor Melick and Mr. Philp. Room 211 afforded office space for Professor Vedder and Mr. Davies, while room 312 was similarly used by Mr. Hitchcock, Mr. Cade, and Assistant Professors Saxton and Gehring. Giving up offices, classrooms and laboratories for our use has undoubtedly inconvenienced the teachers in the Division of Agriculture, but their sacrifices appear to have been made cheerfully and are sincerely appreciated by all teachers in the Department of Civil Engineering.

The tabulation below records the classroom activities of the department for the year, except the single item of one class of 18 students in M. E. 6b, Kinematics, conducted by Mr. Davies in the winter term, for which purpose his services were loaned to the department of Mechanical Engineering. During the same term Mr. Davies carried out an assignment of thirty hours per week in adjusting, cleaning and arranging our equipment of surveying instruments.

CLASS WORK OF THE DEPARTMENT OF CIVIL ENGINEERING FOR THE COLLEGE YEAR 1915–1916.

FALL TERM.

Class.	Subject.	No. of course.	Teacher.	Class room.	Periods of meeting.	No. hours per week.	No. students in class.
Summer Sch. 1915 (2 weeks) Sophomores	Forest Topography.....	C.E.2a	Mr. Cade..................	14 miles n. w. of Cadillac Michigan.	....	50	12
Fall term.							
Sophomores.	Surveying (class)........	C.E. 1a.	Prof. Saxton................	203	5	2	27
Sophomores.	Surveying (class)........	C.E. 1a.	Prof. Gehring...............	109	7	2	25
Sophomores.	Surveying (class)........	C.E. 1a.	Mr. Davies.................	302	5	2	24
Sophomores.	Surveying (class)........	C.E. 1a.	Mr. Davies.................	401	1	2	30
Sophomores.	Surveying (class)........	C.E. 1a.	Mr. Davies.................	111	3	2	26
Sophomores.	Surveying (class)........	C.E. 1a.	Mr. Hitchcock..............	302	7	2	25
Sophomores.	Surveying (class)........	C.E. 1a.	Mr. Hitchcock..............	301	1, 2	2	29
Sophomores.	Surveying (class)........	C.E. 1a.	Mr. Hitchcock..............	213	3	2	30
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Hitchcock, Mr. Philp....	304	3, 4	2	34
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Hitchcock, Mr. Philp....	304	3, 4	2	30
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Davies.................	304	7, 8	2	25
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Davies.................	304	7, 8	2	24
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Davies.................	304	5, 6	2	28
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Davies.................	304	5, 6	2	26
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Davies.................	401	1, 2	2	25
Sophomores.	Surveying (field)........	C.E. 1a.	Mr. Davies.................	304	1, 2	2	26
Juniors.....	Mechanics..............	C.E. 4a.	Prof. Gehring..............	302	1	5	13
Juniors.....	Mechanics..............	C.E. 4a.	Prof. Melick................	109	5	5	16
Juniors.....	Mechanics..............	C.E. 4a.	Mr. Philp..................	403	1	5	13
Juniors.....	Mechanics..............	C.E. 4a.	Mr. Philp..................	213	5	5	16
Juniors.....	Mechanics..............	C.E. 4a.	Prof. Saxton................	203	1	5	14
Juniors.....	Mechanics..............	C.E. 4a.	Mr. Hitchcock..............	401	5	5	12
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Prof. Melick................	203	7	3	19
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Prof. Melick................	203	8	3	21
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Mr. Hitchcock..............	302	2	3	22
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Mr. Philp..................	203	2	3	21
Juniors.....	Adv. Surveying (field)....	C.E. 6..	Mr. Cade, Mr. Hitchcock....	306	6, 7	4	21
Juniors.....	Adv. Surveying (field)....	C.E. 6..	Mr. Philp..................	306	6, 7	4	23
Juniors.....	Adv. Surveying (field)....	C.E. 6..	Prof. Melick, Mr. Cade......	306	3, 4	4	19
Juniors.....	Adv. Surveying (field)....	C.E. 6..	Prof. Melick, Mr. Cade......	306	3, 4	4	20
Jun., Sen...	Surveying Methods (class)	C.E. 2..	Mr. Cade...................	109	1	3	11
Jun., Sen...	Surveying Methods (field)	C.E. 2..	Mr. Cade...................	304	1, 2	4	11
Seniors.....	Graphic Statics.........	C.E. 4d.	Prof. Melick................	306	1	3	17
Seniors.....	Graphic Statics.........	C.E. 4d.	Prof. Melick................	306	2	3	16
Seniors.....	Hydraulics.............	C.E. 5..	Prof. Saxton................	203	3	5	15
Seniors.....	Hydraulics.............	C.E. 5..	Prof. Gehring...............	302	3	5	14
Seniors.....	Hydraulics.............	C.E. 5..	Prof. Saxton................	203	4	5	21
Seniors.....	Hydraulics.............	C.E. 5..	Prof. Gehring...............	302	4	5	20
Seniors.....	Hydraulic Laboratory....	C.E. 5a.	Prof. Saxton................	3	5-8	4	11
Seniors.....	Hydraulic Laboratory....	C.E. 5a.	Prof. Saxton................	3	5-8	4	10
Seniors.....	Hydraulic Laboratory....	C.E. 5a.	Prof. Gehring...............	3	5-8	4	9
Seniors.....	Hydraulic Laboratory....	C.E. 5a.	Prof. Gehring...............	3	5-8	4	9
Seniors.....	Higher Survey (class)....	C.E. 6b.	Prof. Vedder................	111	1	1	12
Seniors.....	Higher Survey (class)....	C.E. 6b.	Prof. Vedder................	111	4	1	15
Seniors.....	Higher Survey (field)....	C.E. 6b.	Prof. Vedder, Mr. Cade......	111	5-8	4	14
Seniors.....	Higher Survey (field)....	C.E. 6b.	Prof. Vedder, Mr. Cade......	111	5-8	4	13
Seniors.....	Bridge Stresses..........	C.E. 8a.	Prof. Vedder................	111	2	3	16
Seniors.....	Bridge Stresses..........	C.E. 8a.	Prof. Vedder................	111	4	3	14
Totals..	48 sections..............			....		175	932

WINTER TERM, 1916.

Class.	Subject.	No. of course.	Teacher.	Class room.	Periods of meeting.	No. hours per week.	No. students in class.
Juniors	Mechanics	C.E. 4b.	Mr. Philp	111	1	5	13
Juniors	Mechanics	C.E. 4b.	Mr. Cade	213	1	5	13
Juniors	Mechanics	C.E. 4b.	Mr. Saxton	203	5	5	12
Juniors	Mechanics	C.E. 4b.	Mr. Philp	111	5	5	13
Juniors	Mechanics	C.E. 4b.	Mr. Hitchcock	302	1	5	12
Juniors	Mechanics	C.E. 4b.	Mr. Hitchcock	302	5	5	14
Jun., Sen.	Agricultural Engineering	C.E. 3.	Prof. Vedder	111	2	5	17
Seniors	Bridge Design	C.E. 8b.	Prof. Melick, Mr. Philp	304	3, 4	8	29
Seniors	Masonry and Arches	C.E. 9.	Prof. Melick	109	F 3, M. W. 5	3	19
Seniors	Masonry and Arches	C.E. 9.	Prof. Gehring	203	1	3	10
Seniors	Masonry and Arches	C.E. 9.	Prof. Melick, Prof. Gehring	304	5–8	4	19
Seniors	Masonry and Arches	C.E. 9.	Prof. Melick, Prof. Gehring	306	7, 8	4	10
Seniors	Pavements	C.E. 10.	Prof. Saxton	203	7	2	15
Seniors	Pavements	C.E. 10.	Prof. Saxton	203	1	2	14
Seniors	Experimental Laboratory.	C.E. 12.	Mr. Cade. Mr. Hitchcock	4, 106	6–8	6	16
Seniors	Experimental Laboratory.	C.E. 12.	Mr Cade, Prof. Saxton	4, 106	2–4, 6–8	6	14
Seniors	Water Supply	C.E. 15.	Prof. Gehring	302	2	4	12
Seniors	Water Supply	C.E. 15.	Prof. Saxton	203	2	4	17
Totals	18 Sections					81	269

SPRING TERM 1916.

Class.	Subject.	No. of course.	Teacher.	Class room.	Periods of meeting.	No. hours per week.	No. students in class.
Sophomores.	Surveying (class)	C.E. 1b.	Mr. Davies	207 Ag.	7	2	18
Sophomores.	Surveying (class)	C.E. 1b.	Mr. Davies	207 Ag.	2	2	19
Sophomores.	Surveying (class)	C.E. 1b.	Mr. Hitchcock	207 Ag.	7	2	21
Sophomores.	Surveying (class)	C.E. 1b.	Mr. Hitchcock	207 Ag.	2	2	26
Sophomores.	Surveying (field)	C.E. 1b.	Mr. Davies, Mr. Hitchcock	109 Ag.	5, 6	4	19
Sophomores.	Surveying (field)	C.E. 1b.	Mr. Davies, Mr. Hitchcock	109 Ag.	3, 4	4	21
Sophomores.	Surveying (field)	C.E. 1b.	Mr. Davies, Mr. Hitchcock	109 Ag.	5, 6	4	18
Sophomores.	Surveying (field)	C.E. 1b.	Mr. Davies, Mr. Hitchcock	109 Ag.	3, 4	4	25
Sophomores.	Surveying Methods (class)	C.E. 2.	Mr. Cade	208 Ag.	5	3	12
Sophomores.	Surveying Methods (field)	C.E. 2.	Mr. Cade	Dairy	3, 4	4	12
Juniors	Topog. Mapping (class)	C.E. 6a.	Mr. Cade	208 Ag.	2	2	17
Juniors	Topog. Mapping (class)	C.E. 6a.	Mr. Cade	208 Ag.	8	2	14
Juniors	Topog. Mapping (field)	C.E. 6a.	Mr. Cade, Prof. Gehring	For.	2	4	17
Juniors	Topog. Mapping (field)	C.E. 6a.	Mr. Philp, Mr. Cade	For.	8	4	14
Juniors	Strength of Materials	C.E. 4c.	Mr. Philp	206 Ag.	3	5	10
Juniors	Strength of Materials	C.E. 4c.	Mr. Philp	207 Ag.	4	5	16
Juniors	Strength of Materials	C.E. 4c.	Mr. Philp	Dairy	5	5	11
Juniors	Strength of Materials	C.E. 4c.	Prof. Gehring	Hort.	3	5	11
Juniors	Strength of Materials	C.E. 4c.	Prof. Gehring	207 Ag.	5	5	11
Juniors	Strength of Materials	C.E. 4c.	Prof. Gehring	207 Ag.	6	5	16
Juniors	Railroad Survey (class)	C.E. 7.	Prof. Melick	208 Ag.	1	3	19
Juniors	Railroad Survey (class)	C.E. 7.	Prof. Melick	206 Ag.	7	3	15
Juniors	Railroad Survey (field)	C.E. 7.	Prof. Melick, Prof. Saxton	Vet.	5–8	4	9
Juniors	Railroad Survey (field)	C.E. 7.	Prof. Melick, Prof. Saxton	Vet.	5–8	4	3
Juniors	Railroad Survey (field)	C.E. 7.	Prof. Melick, Prof. Saxton	Vet.	1–4	4	22
Jun., Sen.	Roads (class)	C.E. 17.	Prof. Saxton	213 Ag.	4	2	14
Jun., Sen.	Roads (field)	C.E. 17.	Prof. Saxton, Prof. Melick	Vet.	3, 4	6	14
Seniors	Contracts, etc	C.E. 13.	Prof. Vedder	208 Ag.	3	3	31
Seniors	Contracts, etc	C.E. 13.	Prof. Vedder	206 Ag.	4	3	31
Seniors	Astronomy (class)	C.E. 14.	Prof. Vedder	208 Ag.	4	2	26
Seniors	Astronomy (field)	C.E. 14.	Prof. Vedder, Mr. Philp	....	Evening	2	26
Seniors	Thesis, 4 sections	C.E. 11.	Prof. Vedder, Prof. Melick, Prof. Gehring, Prof. Saxton	....	....	20	32
Totals	32 Sections	....	....	....	....	129	570

The following text-books have been used in our classes during the year; Merriman & Jacoby's Roofs and Bridges, Vols. I, II, III; Vedder's Notes on Surveying; Merriman's Treaties on Hydraulics; Hancock's Mechanics; Baker's Masonry Construction; Harger and Bonney's Highway Engineer's Handbook; Turneaure and Russel's Public Water Supplies; Folwell's Sewerage; Hosmer's Astronomy; Tucker's Contracts in Engineering; Boyd's Strength of Materials; Allen's Railroad Curves and Earthwork; Breed and Hosmer's Surveying, Vols. I, II; Ingram's Geodetic Surveying; Blanchard and Drowne's Highway Engineering.

The total expenditure by the department during the year for all purposes has been $3,247.72. During the same period the sum of $52.00 was turned in for special examinations, and $626.75 for laboratory fees and other departmental receipts. Of our total annual expenditure as stated above, $946.22 has been used since March 5th the date of the fire, and has therefore been directed toward the problem of reconstruction.

Respectfully submitted,
H. K. VEDDER,
Professor of Civil Engineering.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF PHYSICS AND ELECTRICAL ENGINEERING.

President F. S. Kedzie:

Dear Sir—About two years ago considerable pressure was brought to bear upon the Physics department to provide some means by which a student could enter the College without Preparatory Physics. This request came because many colleges and universities are offering courses in which Preparatory Physics is not required, although such courses are not equivalent to any we give here.

This last year I offered to admit candidates for the Home Economics Course without Preparatory Physics, because the amount of time assigned to Physics had been increased, and the faculty included the agricultural and veterinary candidates in this provision. In June this year (1916) this matter was referred to the Committee of Deans with power for further action, which adopted the following resolution:

"The action of the faculty permitting other entrance credits to be substituted for physics by classes in the Divisions of Agriculture and Home Economics entering in the fall of 1916 or thereafter shall be made retro-active to include all students at present conditioned in entrance physics *who carry ten credits of physics during their college course.*

At the discretion of the head of the Department of Physics, additional work *may* be required of those who do not offer physics for entrance and whose work indicates that extra time is needed."

This must be considered in the nature of an experiment, and it is to be hoped that it will at least be followed by more time being given to physics in the Agricultural Course, for the principles of physics are becoming increasingly important in each of these courses above mentioned.

I have always considered that we give a pretty complete course in physics to the engineering students; three terms with lecture and laboratory work throughout the year. This spring I received a communication from Columbia University to the effect, that some of our engineering graduates were applying for graduate work there, and they wished to find out how much work in physics our graduates had had. On comparing their course with ours, I find they give fifty per cent more time to physics than we do.

On March 5th, this year, the Physics department was burned out of its quarters in the Engineering Building, and since that time has been occupying rooms in the Forestry Building. This fire made a considerable interruption affecting not only those departments whose quarters were destroyed, but all of the departments of the College, more or less, because of the "doubling up" which was necessary.

It perhaps would be proper to put on record here the fact that classes were resumed the next morning (Monday) without any loss of class work. This made necessary strenuous exertions for many others than the members of the departments directly affected. During the spring term we have also met all of our usual classes, and have covered the ground usually covered in that term.

All but the Physics department will return to the new Engineering Building some time this next year. It remains to be seen what permanent quarters can be provided for this department. I do not know that there is any occasion for my discussing the possibilities of the new location at this time, since the department was separated on the first of July from the Department of Electrical Engineering, and the physics work will now be carried as a separate department.

I wish at this time to put on record my appreciation of the way in which all the members of the department have carried this extra burden and made possible a minimum of disturbance in the work of the department.

The Department of Electrical Engineering also suffered the loss of its quarters on March fifth, and has been housed temporarily in the Forestry Building. As in the case of the Physics department, the work has gone on with a minimum of interruption, the same ground being covered during the spring term, as was usual. Considerable apparatus belonging to the Electrical department, was saved.

The department has for some time been considerably interested in helping the farmer to make use of electricity to assist him in his daily life. The two electives in physics, namely: 4a and 4c, were instituted to make an opportunity to study the situation and participate in the matter of providing electricity for the farmer. Now that the two departments are separated and that work goes with the Physics department, I cease to have active connection with that problem but expect to continue activities along that line in some other way.

The development of electric generators automatically controlled so as to keep a storage battery charged on a automobile for operating the electric starter, suggests that the same thing can be done on a little larger scale for the farmer. In this case a varying speed drive, namely, the windmill, can be used similarly to keep a battery charged. This has been an attractive problem for many years but has not so far been satisfactorily solved.

Another matter that is worthy of consideration, is providing the people throughout the State with texts which will enable them to acquaint themselves with the handling of electricity. We have many calls for such information from people who find it impossible to take a course in college. I am inclined to think that bulletins could be written pretty much along the lines of self help books intended for mechanics who are unable to take advantage of school facilities. I quite believe that short course work could be done along this line to good advantage, either in the winter or during the summer.

Respectfully submitted,
A. R. SAWYER,
Professor of Physics and Electrical Engineering.
East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF DRAWING AND DESIGN.

President Frank S. Kedzie:

Dear Sir—I herewith present to you my eighth annual report as head of the Department of Drawing and Design for the year ending June 30, 1916.

The work of the department has been carried on by the following teachers:

Mr. Chace Newman,
Miss Caroline L. Holt,
Mr. Myron B. Chapin,
Mr. Frank D. Messenger,
Mr. Alfred Iddles,
Mr. Earle H. Stewart.

Due to the arrangement of schedule and light attendance, Mr. Chas. R. Todd's place was not filled until the beginning of the winter term by the appointment of Mr. Earle H. Stewart.

My first pleasurable duty is to bear testimony to the conscientious and faithful work of my staff. I have never, since my term in office, had anything but faithful service from the staff; but this year, more notably than previously, the fire destroying the Engineering Building, put this to the test, and the instructors were by no means found wanting. They are due the most appreciative recognition for their actions during these past trying months of readjustment. I may here add that I feel that not sufficient recognition for faithful service is the rule. Much higher efficiency in my opinion, would result if workers were led on to do their best by a little merited appreciation. I think I have demonstrated this to be true in my own experience. I do not believe it would cost any money or breed trouble. The Drawing department has had a uniformly capable corps of instructors throughout my administration; no one has really made a failure of his work, and a number have gone out to more remunerative positions crediting the department with being a good school for their training. In support of this I may mention Mr. Walter G. Ward, Professor of Drawing at the Dakota Agricultural College, and Mr. Carl Head, Professor of Drawing and Machine Design at the James Milliken University, Decatur, Ill.

As remarked, the fire destroyed everything including many valuable personal possessions belonging to the staff. But it was here demonstrated quite well that equipment does not make a college; it is teachers and a condition of intelligent understanding between students and teachers.—Might not some of the money lavishly spent upon equipment be wisely diverted to remunerate good teachers? We were enabled to continue uninterruptedly the classes and the work without—if my memory serves me right,—losing one hour's time. The fire occurring on Sunday morning early, the day was spent in reorganizing and locating so as to start under full headway Monday morning. And, furthermore, no absences are to be recorded those first days following, except one or two throughout the department due to causes in no way related to the fire. Some courses had to be modified because of loss of equipment, but I am sure that the substitutions made resulted in equally beneficial results to the students.

In general the courses have been conducted as heretofore with continuous effort to improve and adapt them to the most modern methods. The new courses Drawing 1c and 2c for landscape gardening students have proved particularly adapted to their needs and are unique I am sure in the breadth of field covered in the short time, and the results in efficiency as shown by the students' work. The instructors should be credited also with having made some valuable changes in the courses in elementary mechanical drawing. I would sum up the situation by saying, we have tried to keep up high standards of scholarship throughout, making no discrimination, as I have mentioned in a previous report, between men and women in this respect.

I would like to mention the need, in my opinion, for a better arrangement of schedule of hours so that the teaching force may be used to best advantage. At present there seems to be too much bunching of classes on certain days and at certain hours. I have mentioned this need before. I feel that the whole program deserves very careful and intelligent study which it does not now get, owing to the method by which it is put together each term. Concentration of responsibility would help matters I am sure.

Retiring this year from my position here and in all probability from the teaching profession in which I have served twenty-three years, I wish to express my appreciation of the College I am leaving. I have spent eight pleasurable years in its service, and have learned to respect its aims and the personnel of its staff very much. I feel a hearty loyalty to the institution which will live with me. I shall follow its fortunes with keen interest. I believe in its future as a growing and progressive institution along the broadest and most useful lines. Our new President has every opportunity to carry out this plan, familiar as he is with every tradition of the institution, and loving the student body both graduate and under-graduate as he does.

The following is a table showing the teaching hours and the distribution of the work among the different instructors.

Respectfully submitted,

VICTOR T. WILSON,

Professor of Drawing and Design.

East Lansing, Mich., June 30, 1916.

Schedule.

Class.	Course.	Instructor.	Fall.		Winter.		Spring.	
			Hours.	No. of students.	Hours.	No. of students.	Hours.	No. of students.
Freshmen Engineers	F. T. 4 a b W. T. 4 e S. T. 5 a b	Newman	6	13	6	14		
		Newman	6	17				
		Newman					3	17
		Newman					3	19
		Newman					3	16
		Newman					6	17
		Chapin	6	16				
		Chapin	6	16				
		Messenger	6	17	6	14		
		Messenger			6	12		
		Iddles	6	17	6	12	9	15
		Iddles	6	13			3	13
		Iddles	6	17				
		Stewart			6	15		
		Stewart			6	12		
		Stewart			6	14	9	20
		Van Buren					6	
		Willoughby					6	
Freshmen Engineers	F. T. 5 a b	Newman	8	12				
Junior Engineers	F. T. 6 W. T. 7	Newman			6	16		
		Messenger	6	17				
		Messenger	6	17	6	14		
		Iddles			6	15		
Junior Agr. Elec	F. T. 1 c F. T. 2 c	Wilson	10	6	10	5		
Senior Agr. Elec	S. T. 3 c	Messenger					10	6
Graduate Special		Wilson	10	1	10	1	10	1
Freshmen H. E., Option	F. T. 1 i W. T. 1 j S. T. 1 k	Wilson			4	33		
		Holt	4	18				
		Chapin	4	19			4	18
		Chapin					4	19
Soph. H. E	F. T. 1 b W. T. 1 d S. T. 3 a	Wilson	6	16			10	29
		Holt	6	19				
		Holt	6	14				
		Chapin	6	12	6	19		
		Chapin			6	16		
		Chapin			6	14		
		Chapin			6	14	6	19
		Stewart					6	15
		Stewart					6	21
		Iddles					10	38
		Messenger					10	39
Junior H. E	W. T. 2 b S. T. 1 l l e	Holt			5	36	6	25
		Holt			5	19	6	14
		Holt					6	3
		Chapin					6	12

REPORT OF THE DEAN OF DIVISION OF HOME ECONOMICS.

President F. S. Kedzie, Michigan Agricultural College :

Dear Sir—Permit me to present the following report for the Division of Home Economics for the year 1915-1916.

The enrollment for the year, exclusive of the Summer School, was 330 as against 299 for the year 1914-1915. The comparative enrollment by classes was as follows:

	1914-'15	1915-'16
Graduates	3	2
Seniors	44	64
Juniors	62	60
Sophomores	70	71
Freshmen	97	120
Special	23	13
Total	299	330

This increase in numbers, though not large, has made necessary readjustments along many lines; as the dormitory, dining-room and laboratory accommodations were inadequate to meet it. It has also seemed essential to make some changes in the plans for the life of the young women and in the regulations governing their social activities, for more than half of the students in the division, aside from those whose homes are in Lansing and East Lansing, were housed outside of the Woman's Building and the problems to be met have been increasingly those of a scattered body of students rather than those of a group living under one roof.

Some changes were made in the instructing force of the division: Miss Mary E. Edmonds was made head of the Domestic Science department; Miss Zella E. Bigelow, instructor in Domestic Art; Miss Edna Garvin, instructor in Domestic Science and Art; Miss Margaret M. Justin, Extension Specialist; Miss Anna Bryant Cowles, assistant in Extension Work. A new position of House Mother was filled by Mrs. Cornelia R. Lindsay, for the year. Mrs. L. L. Peppard, head of the Domestic Art department was away from the College on leave of absence during the spring term, studying at the University of Chicago. It is with regret that we lose from the division this year, Miss Florence Farwell who has done such efficient work as House Director; Miss Clara King Morris, instructor in Domestic Science; and Miss Lyla Edgerton, instructor in Music.

The question of suitable dormitory accommodations has continued to be one of the pressing questions in providing for the women of the College. The Woman's Building has been improved during the year by steel ceilings in the main corridors, offices and laboratories; by bringing soft water into the house; and by installing a passenger elevator. The elevator, especially, added greatly to the comfort and health not only of those who have lived in the building, but also of those who have come to the dining-room from the outside houses. The experiment which was tried this year of housing twenty girls in a small house leased by the College, and known as the "College Cottage" has proved satisfactory both to the students living in it and to those in charge of the division. With a matron and a teacher in residence, a home life has been possible which gives promise of making the transition from normal home life to the life of the large dormitory less difficult. It is the plan for next year to lease a second house, on Albert Avenue, which will furnish dormitory accommodations for thirty students and will have, in addition, a dining-room sufficiently large to provide for a boarding club of fifty members.

The new course of study for the division, which was outlined last year, went into effect this year for freshmen and juniors, and though its efficiency cannot be determined until it has been longer in use, the slightly greater flexibility and the concentration of effort on fewer subjects which characterized the course, have seemed to give satisfaction to the students and to strengthen the work of the departments concerned. A few changes will be made for next year that are indicative of the direction in which the work of the division is tending.

Two five credit courses in Physiological Chemistry have been added as requirements for juniors, prerequisite to the work in Dietetics and the senior courses in Foods. This will enable the department to offer more advanced work in Domestic Science than could be offered before, and will strengthen existing courses.

A change will be made in the technical work of the first two years. Either music, or drawing and English, has been a requirement throughout those years. In has been felt that it would help to foster a real interest in music and an appreciation of it,—as well as raise college standards,—if music should be made elective and the technical work in it be given college credit only when a certain stage of proficiency had been attained by the student, and when the work was combined with courses in musical theory. With this in mind, free, required music has been dropped from the course and the two credits per term which were given to it have been added to the regular technical work of the division.

It has been the hope of the division to have, at some time, a house which could be used as a practice house for senior girls, in order that they might have the opportunity to apply to the management of a home, the knowledge and skill which they had acquired in the various courses in Domestic Science and Domestic Art. This hope is to be realized by the action of the State Board in giving to the division the house which has been for so many years the home of the President of the College, that it may be used as a Senior House. It is planned to equip the house with modern facilities for home keeping that will be simple, attractive and in accordance with the standards of the College. Twenty seniors will be in residence each term and will, under the immediate direction of the teaching staff of the Domestic Science department, carry on the work and life of the home. As far as possible, the furnishing and equipping of the house will be done by the classes in Domestic Science and Domestic Art. We believe this will mark a great advance in the efficiency of the work in the junior and senior years.

The division has endeavored during the year, to relate its work more closely to the needs of the women of the State and the results of the increased contact with them have been illuminating and helpful. Partly as a result of this endeavor, a plan has been outlined by representatives of a number of women's organizations in the State for uniting the efforts of the Michigan Home Economics Association; the Teachers of the State; the Federation of Women's Clubs; the Grange; the Farmer's Clubs; the Gleaners; the State Nurses' Association; and other interested organizations, with those of the College, toward introducing home economics into all the public schools of the State as rapidly as local conditions will permit.

It is with pleasure that I report the progress that has been made toward raising the permanent Student Aid Fund of $3,000. Mrs. C. B. Collingwood, who has been President of the East Lansing Woman's Club and Chairman of the Committee of the State Federation for the fund, has secured the interest of many of the Alumnae of the College as well as of many of the Women's Clubs, and the amount of $1,300 is already available for use. A committee consisting of one member elected by the Alumnae Association; one, appointed by the Michigan Federation of Women's Clubs; and the Dean of the Division will have charge of administering the fund.

The Alumnae have also been active in furnishing a guest room in the Woman's Building that will enable the division to extend, again, the hospitality to college guests which the crowded condition of the Building has made impossible in recent years.

In reviewing, after two years of work, the progress which has been made and comparing it with the standards which, as a division, we wish to establish and maintain for our students along the lines of scholarship and personal development, as well as along social lines, it has seemed to me that our greatest need at the present time is that of a Home Economics Building in which the class work of the division can be carried on apart from the dormitory and social life. There are two reasons for this decision:

1. As long as laboratories and lecture rooms are connected physically and in the minds of the students with the more informal social and dormitory life, it is much more difficult to secure the attitude of mind that is most conducive to scholarship and the recognition of the importance of regularity and concentration in work.

2. The increase in numbers is already making it necessary to consider the equipping of new laboratories in both Domestic Science and Domestic Art, and the economy of money, and of the time and energy of the teaching force that will be secured by arranging for the work to be done in one well equipped building will be great. It will also release rooms in the Woman's Building, which will help to relieve the over crowded condition there.

Permit me, therefore, to ask your consideration,—and that of the State Board of Agriculture,—of the need of more laboratories and class rooms to meet the demands which are being made upon us by the increase in numbers, and of the possibility of meeting this need by erecting, in the near future, a separate Home Economics Building.

Respectfully submitted,
GEORGIA LAURA WHITE,
Dean, Division of Home Economics.

East Lansing, Mich., June 30, 1916.

REPORT OF DEAN OF VETERINARY DIVISION.

President Frank S. Kedzie, College:

Sir—I have the honor to submit herewith a report of the Veterinary division for the academic year ending June 30, 1916.

Faculty and Teaching: The most noteworthy fact as regards the faculty for the past year has been the development of the departments of Veterinary Anatomy and Animal Pathology, together with appropriate recognition of the worth and services of men connected with these phases of work ever since the subjects, under their direction, were added to the courses of study of the division, through placing them, Dr. Frank W. Chamberlain and Dr. E. T. Hallman, respectively, in responsibility and giving them places upon the college faculty. By this action of the State Board of Agriculture the force of the Veterinary division has been augmented to six men entirely engaged in such work as is comprehensively grouped under the heads of medicine, anatomy, pharmacology, pathology and surgery; this, naturally, is exclusive of instruction students receive in animal and dairy husbandry, bacteriology, botany, chemistry, English, entomology, military science, physiology and zoology, work that has not only been efficient, but that has been offered with an evident desire to cooperate and serve the division in a highly commendable manner that is gratefully appreciated. Indeed, the past year has again served to demonstrate the indisputable advantages of having a veterinary school at an agricultural college, where the educational requirements meet the larger needs of problems incidental to health and scientific agriculture, especially as the latter is developed through animal husbandry; furthermore, in this connection is it appropriate to recall that it is the boys from the farm, naturally attracted to the agricultural college when seeking higher education, that, as a class of students, have as a whole the early training and environment which furnish the best basic equipment and adaptability for veterinary work.

As was suggested in last year's report the faculty of the division urgently needs additional help to more equally distribute class work, if it is to continue with that high degree of efficiency which has characterized the work from the first, and to take care of the growing demands incidental to a progressive policy. Naturally, the cost up to this time for maintenance of the division, in proportion to number of students enrolled, may have appeared excessive as compared with other courses; this was due largely to the necessity of supplying equipment essential to an adequate schedule for studying modern veterinary medicine. With the steady increase in number of students, as will be shown tabulated later, and the annual addition of new courses, the figures have materially changed. During the year just closed, without listing any student a second time even though the individual takes several subjects or appears on the roll for three successive terms, we have given instruction to 412 different students, including sixty-nine in the regular full veterinary course, ninety-one agricultural students electing veterinary science, and the first and second year short courses, including both the five months' and eight weeks' classes; the later swelling the aggregate to an average in excess of three hours daily for a period of sixteen weeks devoted exclusively to work with students of agriculture.

The efficiency of our work has been materially enhanced through being able to retain the same teaching staff year after year and the praiseworthy efforts put forth by each individual forecasts an encouraging outlook for the approaching year. The classroom work, extensively supplemented in some instances, is distributed in the re-adjusted schedule as follows:

Instructor.	Fall. Hours per week.	Winter. Hours per week.	Spring. Hours per week.
R. P. Lyman	10	17	9
F. W. Chamberlain	23	25	25
J. S. McDaniel	16	14	19
E T. Hallman	6	10	9
J. P. Hutton	29	22	17

As has already been intimated an institution claiming a progressive policy must be alive to the constantly increasing demand for an extension of its scope of usefulness to the people of the State, and moreover through increased offerings is the opportunity to the prospective student broadened. With the work already in hand and by offering projected plans for future development both in the teaching facilities and extension work may we amply demonstrate the validity of our claim to a needed increase in the present corps of instructors. The courses, we deem it feasible to introduce at this time, aim toward development along two lines; for veterinary students and veterinarians on the one hand and students of agricultural pursuits on the other.

With the ever increasing responsibilities obligatory upon the trained veterinarian and new avenues constantly broadening the field of work, the state college should be keen to the necessity of offering its facilities to the graduate practitioners of Michigan and arrange courses to give them opportunity to keep in the forefront and increase their efficiency. We should then, as soon as possible, and indeed, ought at once, make arrangements to offer short courses and conferences for practitioners, plan a week schedule for the winter season when professional duties are less active, in which should be included attractive methods for pursuing modern surgery, for studying parasitic diseases, live stock sanitation and research into problems incident to infectious diseases, etc.

From the standpoint of the student the work offered has constantly been of high grade with additions and improvements from time to time, and if manifesting weakness at any point we believe it is along the line of medical clinic. Efforts are to be made with a view to improvement in this phase of work and it is possible that through the cooperation of the Lansing Sanitary Inspector, an alumnus of this division, we may find a way to increase our clinics in dairy cow practice which is becoming a large factor in the daily work of a practitioner. Our new schedule will permit ample time for some arrangement which should be of distinct advantage to the College and tend to make strong practitioners.

During the past two years advanced courses have been added in veterinary anatomy and animal pathology, thus affording graduate veterinarians a chance to pursue post graduate studies. Recent graduates have shown an inclination to elect this work and it might serve to encourage them if one or more of such men were yearly employed as assistants to do a small amount of laboratory teaching; this is we believe practicable and can be accomplished by offering assistantships with, at least, quarter time allowance.

Turning to the second phase of additional teaching and courses for students engaged in agricultural pursuits, we are persuaded that there is need for revising the Veterinary Science course now elective to senior and junior students and we have recently completed an outline including both required and elective work, which, if adopted, thus combining both laboratory and lecture work, will unquestionably make the course more valuable. The aim of the revision is to give the student as much definite comparative knowledge of the structure and function of the animal body as time will permit; to embrace a knowledge of preserving and promoting health of farm animals; to consider briefly certain contagious and infectious diseases and to discuss common diseases and accidents as regards cause, symptoms, prevention and first aid treatment. We believe it would be to advantage if the required portion of the work could be scheduled early in the Agricultural course.

Another course we desire to offer is an elective on poultry diseases. Poultry raising is an industry worth millions of dollars to the agriculture of this country but subject to the ravages of both parasitic and contagious diseases. Accordingly lectures with some laboratory study, extending a single term, should prove popular and beneficial, but this would mean under present conditions over crowding the schedule of available instructors; and again emphasizes the need for additional help if the division is to progress, realize its ambitions and reach out.

On a previous occasion we suggested the advisability of establishing a six year course of study enabling students to simultaneously pursue work for a Bachelor of Science degree in Agriculture and a Doctor's degree in Veterinary Medicine. We have worked out a tentative schedule which includes the entire required work of both the Agricultural (animal husbandry) and Veterinary courses, together with a fair distribution of the electives of the former and believe the plan to be worthy of serious consideration. This idea has since our previous mention been fully developed and inaugurated in at least two state colleges, Michigan Agricultural College should have been leader in this as it was in developing higher standards for education of the veterinarian.

The Clinic. Reviewing the results of the first full academic year with the new building, we discover that it served as an impetus and added material benefit to the work for which it was especially designed, surgery and clinic. Clinic has previously been referred to as viewed from the standpoint of medical cases and when we endeavored to show how we may possibly improve this phase of the practical instruction so essential if we can hope to make a large proportion of our graduates competent as general practitioners, but, on the other hand, we have only commendation for the continued high grade and excellence of the surgical clinic. Each college year showing development, the recent one has exceeded any previous equal period, and has furnished each member of the senior class more than one hundred different cases upon which to study symptoms, become familiar with methods of treatment and practice methods of handling. The new schedule will increase the total clinical hours from 592 to 780 hours. Below is appended a list of medical and surgical clinics as submitted by Dr. J. P. Hutton, Clinician in charge:

A tabulated report of the medical clinic for large and small animals treated from September 1, 1915, to July 1, 1916:

	Horses.	Cattle.	Sheep.	Swine.	Dog.	Cat.	Poultry.	Total cases.
Azoturia	2							
Alopecia		1		1	3			
Actinomycosis		2		1				
Bronchitis	2				3	2		
Chorea					4			
Conjunctivites	1				2	5		
Constipation		1						
Cystitis					2			
Congestion of Brain	1					1		
Colic, Engorgement	1							
Colic, Obstruction	1							
Colic, Spasmodic	4							
Colic, Tympantic	2							
Coleitis							2	
Eczema, Moist		1			3			
Eczema, Squamous	1				5			
Endocarditis	2							
Emphysema, Pulmonary	3							
Forage Poisoning		2	1					
Goiter	2	1			3			
Gastro-intestinal Catarrh, acute	1	6				1	1	
Gastro-intestinal Catarrh, chronic	11	2						
Gastric Indigestion					2			
Helminthiasis				4	11	2		
Hog-cholera				12				
Influenza	59							
Intestinal Intoxication			1	6	2		7	
Impaction of crop							2	
Lymphangitis	4	2						
Laryngitis	5				2			
Laminitis	2							
Mange Demodex					12			
Mange, Sarcoptis					1	4		
Malignant Catharrhal Fever		1						
Nephritis					1			
Otitis					3			
Osteoporosis	1							
Poisoning					1	1		
Paralysis, Post Partum	1							
Phthiriasis	6				12			
Peritonitis	1							
Pyemic, Arthritis	1							
Pneumonia	1	2						
Roup							6	
Strangles	5							
Stomatitis	1							
Tetanus		1						
Urticaria	1	2						
Totals	122	24	2	24	72	16	18	278

A tabulated report for the surgical clinic for large and small animals treated from September 1, 1915, to July 1, 1916.

	Horses.	Cattle.	Sheep.	Swine.	Dog.	Cat.	Poultry.	Total cases.
Abortion		8						
Atrophy of Gluteals, (Due to Azoturia)	1							
Abcesses	9	3			1	1	1	
Atresia of Teat Duct		7						
Atrophy of Shoulder Muscles	4							
Bursetis Intertubercularis	2							
Castration, Simple	4	3			1	13	2	
Castration, Cryptorchid	2							
Contusion	4	3						
Cocked Ankle	3							
Dehorning		28						
Dermatitis Verrucose	1							
Dystokia	2	5						
Ear trimming					21			
Empyema of Sinus	3							
Examination for Pregnancy	1	4						
Endometritis		8						
Fistula, Withers	2							
Fistula, Bone	1							
Fistula, Sinus	6							
Fistula, Dental	1							
Fistula, Salivary	1							
Fracture	1		1					
Gonitis, Acute	3							
Gonitis, Chronic	4							
Hernia, Umbibical	2			4				
Hernia, Ventral	2							
Hematoma	4				1	1		
Hypertrophy of the Nictitans Membrane					2			
Inflammation of the Heels	2							
Imperforate Arms		1						
Keratitis	3	3			4	2		
Laryngeal Hemiplegia	13							
Luxation of Patella	1							
Mammitis	1	5						
Metorrhogia		1						
Navicular Disease	7							
Ovariotomy	2				51	6		
Poll Evil	1							
Paralysis, Rectal					3			
Paralysis, Facial	3							
Paralysis, Pharyngeal	1							
Phymosis	2	1		1				
Pododermatitis	7							
Penetrating Street Nail	3	1						
Post Partum Paresis		1						
Pyometra	1	10			1			
Prolapse, Vaginal					1			
Persistant Urachus	3							
Quittor	5							
Ring Bone	9							
Retained Placenta	3	8						
Spavin, Bone	7							
Spavin, Bog	3							
Side Bone	6							
Splints	11							
Scratches	5							
Shoulder Lameness	3							
Sterility		31						
Tail, Amputation of					15			

	Horses.	Cattle.	Sheep.	Swine.	Dog.	Cat.	Poultry.	Total cases.
Thoroughpin	2	......	......	......	......	......	......	......
Tendon Contraction	3	......	......	......	......	......	......	......
Tumors, Inoperable	1	......	......	......	......	......	......	......
Tumors, Removed	8	1	1	......	3	......	1	......
Teeth, Sharp and Irregular	18	......	......	......	......	......	......	......
Teeth, Repelled	2	......	......	......	......	......	......	......
Teeth, Floated	21	......	......	......	......	......	......	......
Teeth, Truncated	7	......	......	......	......	......	......	......
Thrush	2	......	......	......	......	......	......	......
Wound, Lacerated	8	......	......	......	......	......	......	......
Wound, Contused	2	......	......	......	1	......	......	......
Wound, Incised	2	......	......	......	......	......	......	......
Wound, Penetrating	2	......	......	......	......	......	......	......
Wound, Caustic	3	......	......	......	2	......	......	......
Totals	246	132	2	5	117	23	4	529

Students and Alumni: Realizing it was becoming more manifestly evident each year that courses already included in the curriculum or demanding recognition of veterinary colleges lacked the time essential for adequate instruction, this division from the beginning pioneered in demanding an entrance requirement of fifteen units together with four years of under-graduate work. In the face of a competition incident to lack of age, our higher standards of entrance requirements and a longer course, we have demonstrated an ability to prepare men the equal of any in competitive examination, and equally efficient as practitioners, showing at the same time a steady consistent growth in the number of students registered annually.

Our graduates, though numerically few, serve to demonstrate the diversified field of opportunity and bid fair, through the value of their industry, to return substantial dividend upon the investment by the State. In the appended table is shown the number of students by classes from year to year, and graduates accredited to the division together with vocational occupations.

CENSUS OF VETERINARY DIVISION.

	College year of 1910-11.	College year of 1911-12.	College year of 1912-13.	College year of 1913-14.	College year of 1914-15.	College year of 1915-16.
Freshmen	x0	*4	8	11	19	24
Sophomores	5	5	10	10	12	18
Juniors	0	5	4	10	9	12
Seniors	0	0	1	3	10	6
Total year enrollment	5	14	27	34	50	60
Graduates	0	0	1	2	10	6
Entered previously as sub-freshmen	2	2	4	xx2	4	0
Graduates engaged in practice	....	....	....	1	4	**4
Graduates with Bureau of Animal Industry	....	....	....	....	1	1
College or investigation work	....	....	....	1	2	....
Graduates in the U. S. Army	....	....	....	....	1	....
Graduates engaged as Milk Inspectors	....	....	v1	....	1	....
Graduates engaged in Commercial Biologies	....	....	....	....	1	....
Graduates taking post-graduate work	....	....	....	....	....	1
Per cent of graduates in or contemplating practice at this time	....	....	....	....	....	53%

v City Sanitary Inspector and practitioner.
x First freshman class 1912-13.
xx Discontinued with fall of 1914.
* No regular freshman class, four special students.
** Not all definitely settled when report was written.

Research: Naturally, our first duty is the making of men competent to apply the knowledge and facts acquired during their college career, but, even so, we must not remain ignorant of the enormous resources invested in Michigan livestock and the present high annual death toll, and we believe the valuation of animals in the State, approximating $175,000,000, warrants our urging further resources (through intimate relationship with the State Experiment Station or otherwise) that will permit of our active cooperation toward curtailing, if possible, some of the annual losses sustained through animal diseases. Taking federal statistics, January 1, 1916, estimating the nation's investment in farm animals at $6,002,784,000, with losses during 1915 of $222,850,000 or .037% and applying these figures to Michigan, we can assume that, during 1915, farm animal losses within its borders amounted to or even exceeded $6,000,000. Now, no disease can be said to be understood and worked out in every essential detail; but we must admit that many are preventable and that the ravages of others, of epizootic and infectious type, can be very materially lessened. Here then is a field in which we ought to be at work, a field appreciated by at least four states, New York, Pennsylvania, Kansas and Iowa, where facilities are afforded the veterinary colleges to engage themselves with, and investigate problems incident to animal disease.

Under our present organization a closer relation can be discovered between argicultural and veterinary affairs, but we are even yet holding back, although there is great opportunity to work to the advantage of the livestock interests through increasing veterinary efficiency on the one hand and, on the other, discovering if possible, better ways for preventing animal loss. The report from the Department of Animal Pathology will show that during its first year it has filled an important and growing demand in the field of diagnosis. A quantity of material has been sent here from veterinarians, farmers and the State Live Stock Sanitary Commission for diagnostic information; this should be encouraged as it naturally adds value to student instruction as well as serving the people of Michigan. There is need and measures should be found to permit us to inaugurate, investigation work upon a larger scale upon problems incident to forage and plant poisoning, the so-called Grand Traverse disease, poultry diseases, parasitic disturbances, diseases of swine; and, indeed, numerous economic problems in prophylactic medicine are worthty of consideration by the Veterinary division.

Anti-Hog Cholera Serum Manufacture. Beginning July 1, 1908, the College undertook to manufacture and distribute anti-hog cholera serum under the supervision of the Department of Bacteriology and Hygiene. This work, September 1, 1915, was transferred to the recently established Department of Animal Pathology, thus becoming a part of the Veterinary division. The plant has continuously manufactured anti-hog cholera serum for the benefit of Michigan swine growers, and during the past five years that Mr. W. S. Robbins has had immediate charge of production, the output has annually increased from 135,000 cubic centimeters to an amount in excess of 648,000 c. c. for the fiscal year just terminated, with a reduction in price from four cents per c. c. to .01½ cents per c. c.; and this without any expense to the College as maintenance, equipment, salaries, etc., have been taken care of through receipts. That this demand for serum will continue is unquestioned, as farmers are fast becoming familiar with the value of biologic therapeutic agents in combating infectious disease, an education which is rapidly spreading through the influence of county agriculturists, county live stock agents, veterinarians and others.

The serum distribution is indisputably of great economic value to animal husbandry and indirectly to meat food consumers. If its distribution is to be continued under public control at prices so favorable, and the writer hopes that it may, the work should not only be encouraged but advanced in every feasible manner. A request has already been placed in the hands of the Board for permission to enlarge the anti-hog cholera serum plant and we trust that this petition will be favorably considered with a further provision for making arrangements not only for increasing the output but for facilitating provision for an adequate bleeding room, immunizing quarters, storage room, improved sanitary arrangements, further equipment, etc., all of which the plant can take care of through the output. Again, I would ask that measures be provided for putting the plant on a recognized footing through obtaining federal license. We do not seek this government recognition for purposes of increasing the sales or unloading a surplus through interstate shipment, for I maintain the plant should be conducted for benefit of Michigan swine growers. The suggestion is with a view to placing our product above reproach and giving it that status its quality warrants.

Extension Work. During the past year members of the division have engaged whenever possible in Extension work, furnishing information relative to the economic importance of controlling animal disease and in so doing have taken active part in grange meetings, institute work, farmers week schedules, agricultural meetings and veterinary gatherings. Considering it is work of utmost importance both to the division and to agricultural progress, it offers another argument for increasing our teaching force thus facilitating its greater efficiency.

Again, if, on the one hand, county agents are of value to agricultural progress and, on the other, it is conceded that veterinary control work is the very foundation of successful animal husbandry, we are not unreasonable in urging the engagement of a graduate veterinarian as an agricultural agent to educate the rural communities with a view to conserving the resources now invested in the animal industry of Michigan.

The American Veterinary Medical Association convenes in annual meeting in Detroit during the latter days of August; some of us have for years been identified with the organization, all connected with the division are members; it would seem fitting were some substantial effort made by the College toward taking active part in helping to entertain the national gathering.

Requirements and Recommendation: The remarks included under this paragraph title, without attempting to overshadow the suggested requirements already included within this report, serve particularly to emphasize our present most urgent need.

With instruction improving and becoming more efficient; with research work advancing in all phases of animal husbandry or agriculture; with our material equipment accumulating and the student enrollment steadily increasing each year our immediate requirements are strongly in evidence and in view of our pressing demands we urge you to recommend the division to the Board for help as herein outlined.

The establishment of the division in the winter of 1910, found the building equipment and teaching facilities entirely inadequate for a well rounded veterinary course and we accordingly immediately undertook to develop a projected plan for improving and increasing our teaching. This plan as already submitted to the Board proposed a group of four buildings designated respectively surgery and clinic, anatomic and pathologic laboratory, pharmaceutical and physiologic laboratory and lastly a medicine and administrative building, these so located in the form of a square as to embrace a court upon rear of which would face the present surgery and clinic building thus affording an adequate outdoor enclosure. The time did not then appear propitious to carry out these plans further than the early erection of our excellent, fireproof Surgery and Clinic Building even though it was even then difficult to determine what solution to make of the problem for housing anatomical work. At present the microscopic laboratories of anatomy and pathology courses are temporarily housed in the second story of the new building with gross anatomy now moved to the east wing of the old Veterinary Building, but both departments have already so outgrown their present quarters as to greatly endanger efficiency with the increasing enrollment.

Our recommendation is a building—Anatomy and Pathology Building—for immediate combined use of the aforementioned departments, a building so arranged as to provide microscopic laboratory facilities for microscopic anatomy including histology and embryology and for pathology, quarters for museum collection and display, for postmortem work, for gross anatomy or dissection, for both veterinary and agricultural students and such other needs as shall serve the departments and where they can be adequately housed to give satisfactory instruction in these important technical branches of the course. I invite inspection of our present quarters during class room periods and further call attention to the equipment in buildings and material in the veterinary departments of other state institutions where sums exceeding $200,000 have been appropriated. This building we believe can be erected for a sum not in excess of $50,000 and would undoubtedly serve for some time to come.

In closing let me again commend those engaged in the instruction work of the division for their painstaking and efficient work—I beg to remain, sir

Yours very truly,
RICHARD P. LYMAN,
Dean of Division of Veterinary Science.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF ANIMAL PATHOLOGY.

President F. S. Kedzie, College:

Dear Mr. President—I herewith submit my first annual report on the work of the Department of Animal Pathology for the fiscal year ending June 30, 1916.

The instruction work given by the department for the year is as follows:

FALL TERM.

	No. of students.	Hours per week.
Pathology 18	10	7
Pathology 20	9	2

WINTER TERM.

	No of students.	Hours per week.
Pathology 16	7	5
Pathology 21	7	4
Pathology 22	7	1

SPRING TERM.

	No. of students.	Hours per week.
Medicine 4 c	7	4

One of the students listed in Pathology 18 is a graduate student working for the M. S. Degree and pursued this course as a minor throughout the year. It is gratifying to note that animal pathology is attracting the attention of graduate students and I am pleased to report that three graduate students have planned to pursue the course for the coming year; one who will take it as a major and two who will take it as a minor.

It will be a policy of the department to offer its work not only to veterinary students but to others interested in animal diseases who are qualified to pursue it.

I regret to report that very little has been accomplished in the nature of extension work in animal diseases. It appears that there is a great opportunity for service in this particular field. The work of the department has been limited to answering letters asking for information and to some institute and one week school work. On September 17th, 1915 the writer attended a meeting of the farmers at Maple Grove school, St. Joseph county, and gave a talk on hog cholera.

October 21, 1915. Attended a meeting of the State Guernsey Breeders' Association at Marshall and talked on abortion and sterility in cattle.

October 26, 1915. Accompanied Mr. C. L. Coffeen, County Agent, Lenawee county, on a trip through the county in the interest of hog cholera control work.

December 10, 1915. Investigated disease of western lambs on farm of Mr. B. near Richland, Kalamazoo county. Trouble found to be due to tape worm infestation. (Thysanasoma actinioides).

December 16, 1915. Attended meeting of Farmer's Club, Three Oaks, and gave talk on hog cholera.

December 27, 1915. Attended one week school at Saginaw Town Hall and gave instruction in contagious abortion, parasitic disease, disinfection and disinfectants and stable hygiene.

January 4, 1916. Investigated disease of hogs near Kalamazoo. Trouble found to be dietary.

February 10. Attended round-up institute at Flint and gave talks on stable hygiene and infectious diseases of live stock.

February 17. Attended farmers' institute at Portland and gave talk on infectious diseases of live stock.

It has been the privilege of the writer to continue to serve the State Live Stock Sanitary Commission during the past year as Animal Pathologist. It is to be hoped that the present relation of the department to the Commission will continue in the future. This relation not only affords an opportunity for us to reach the people and become more familiar with diseased conditions of live stock throughout the State but furnishes us with an abundance of diseased animal tissues which are of great value in our instruction work. The greater part of our work for the Commission consists in the examination of diseased animal tissues sent to the laboratory, but occasionally a trip is made to investigate some animal disease. During the past year the following trips have been made for the Commission.

September 15, 1915, Kalamazoo.
September 25, 1915, Adrian.
October 2, 1915, Kalamazoo.
November 19, 1915, Leslie.
March 30, 1916, Ionia.
April 27, 1916, Howell.

AUTOPSIES AND EXAMINATIONS OF ANIMAL TISSUES.

During the past year we have held autopsies on animals as follows:

Hogs	38
Chickens	26
Sheep	15
Cattle	8
Horses	5
Dogs	3
Cats	1
Total	96

Among these we have found:

Hog cholera	11
Purulent pneumonia, hog	6
Lobar pneumonia, hog	4
Hepatitis, hog	3
Hepatitis and pericardites, hog	1
Gastro-enteritis, hog	1
Verminous pneumonia, hog	1
Acute gastro-intestinal intoxication, hog	1
Parasitic blocking of the bile duct with icterus, hog	1
Hydro nephrosis, hog	1
Septicaemia, hog	1
Rupture of abdominal blood vessel, hog	1
Tuberculosis, chicken	4
Broken egg in oviduct, chicken	2
Pneumonia, chicken	1
Necrotic stomatitis, chicken	1
Intestinal and external parasites, chicken	1
Impaction of crop, chicken	1
Roup, chicken	1
Catarrhal enteritis and taeniasis, chicken	1
Chronic peritonitis, chicken	1
Contagious epithelioma and diphtheria, chicken	1
Chronic hepatitis with hypertrophy and dilation of left side of heart, chicken	1
Thrombosis of bicuspid valve of heart and dilation of left auricle, chicken	1
Abnormally developed heart, chicken	1
Constipation, chicken	1
Stomach worms, sheep	8

Purulent pneumonia and pleurisy, sheep	2
Thysanasoma actinioides, sheep	2
Nephritis, sheep	1
Constipation, lamb	1
Pulmonary and gastric parasites, sheep	1
Acute indigestion, sheep	2
Metritis caused by dead foetus, sheep	1
Catarrhal enteritis, calves	2
Gastro-intestinal intoxication, calf	1
Lobar pneumonia, calf	1
Mastitis, cow	1
Purulent pneumonia, cow	1
Malignant catarrh, cow	1
Pneumonia and uncinariasis. (Bunostomum phlebotomum) calf	1
Pyo metritis, horse	1
Acute peritonitis from hepatic abcess, horse	1
Phlegmon pectoral muscles, horse	1
Necrosis larynx, and stenosis of trachea, horse	1
Gastro enteritis, dog	1
Distemper, dog	1
Peritonitis, dog	1

In the case of eighteen autopsies held it was not possible to make a definite diagnosis.

There have been 125 examinations of tissues from animals during the past year. In some cases the tissues have undergone such post mortem decomposition as a result of improper packing that a diagnosis is not possible when the material reaches the laboratory.

Out of these examinations we have recorded the following cases:

Hog cholera	4
Hydronephrosis hog	1
Cystic kidney and necrosis of kidney, hog	1
Necrobacillosis, foot of hog	1
Purulent pneumonia, hog	1
Actinomycosis, mammary gland, sow	1
Malignant catarrh, cow	2
Fibro sarcoma, cow	2
Fibroma, cow	1
Endotheliomata heart cavity, cow	1
Papilloma, cow	1
Tuberculosis, cow	2
Necrotic laryngitis and glossitis, cow	1
Rabies, cow	2
Necrosis of liver, cow	2
Oesophagostomum inflatum, cow	1
Actinomycosis, cow	1
Traumatic pericarditis, cow	1
Purulent pneumonia, cow	1
Haemorrhagic septicaemia, cow	1
Oesophagostoma Columbiana, sheep	3

Verminous pneumonia, sheep	2
Chondro osteoma, horse	1
Adeno fibroma, horse	1
Fibroma, horse	2
Papilloma, horse	1
Osteo carcinoma, horse	1
Sclerostoma equinum pancreas, horse	1
Albuminuria, horse	1
Phthiriasis, horse	3
Portal cirrhosis, horse	1
Encapsulated yolk, abdominal cavity, chicken	1
Epithelioma, chicken	1
Roup, chicken	1
Hepatic abscess, chicken	1
Diphtheria, turkey	1
Demodex scabies, dog	3
Sarcoptic scabies, dog	1
Rabies, dog	1
Trichocephalus depressiusculus and ascaris marginata, dog	1
Sarcoptic scabies, cat	1

Mr. W. S. Robbins who has continued in charge of serum production submits the following financial statement of serum production for the past year:

FINANCIAL REPORT ON HOG CHOLERA SERUM PRODUCTION.

Feed, concentrated	$1,180 10
Hay, straw and roughage	63 83
Swine	2,468 14
Labor	3,040 00
Apparatus and sundry items	279 87
Total	$7,031 94
Actual receipts for serum and virus and outstanding accounts	$10,386 53
Actual receipts for pigs	1,262 21
Value of tested serum on hand at 1½c per c. c.	3,045 00
Value of hogs in work, on hand	1,120 00
Value of hogs not in work, on hand (market price)	382 50
Total	$16,196 24
Value of products on hand July 1, 1915	5,655 00
Actual value of products to date	$10,541 24

SERUM.

Total number c. c. tested serum on hand July 1, 1915	96,400
Total number c. c. untested serum on hand July 1, 1915	287,000
Total number c. c. drawn and mixed during year	552,015
Total	935,415
Total number c. c. serum sold July 1, 1915 to July 1, 1916	686,660
Total number c. c. used for testing and experimental purposes	22,000
Total number c. c. used on College herd	17,755
Total number c. c. mixed and tested, on hand July 1, 1916	203,000
Total number c. c. breakage	6,000
Total	935,415

Respectfully submitted,
E. T. HALLMAN,
Associate Professor of Animal Pathology.
East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF ANATOMY.

F. S. Kedzie, President, Michigan Agricultural College:

Dear Sir—Accepting the opportunity, I herewith make the first annual report for the Department of Anatomy which has been officially recognized for the past year only as an individual member of the Veterinary division.

The work of the department has been handled entirely by myself except for three hours' assistance in laboratory during the fall term rendered by an undergraduate student. The following table which is self-explanatory shows in part the work done:

	Course.	Lecture. Hours.	Laborat'y. Hours.	Total. Hours.	Students. Hours.
Fall Term:					
Anatomy	2 a	13	117	130	20
Anatomy	3 a	26	78	104	21
Anatomy	4	13	108	121	5
Winter Term:					
Anatomy	1 a	24	72	96	19
Anatomy	2 b	12	72	84	12
Anatomy	3 b	24	72	96	16
Spring Term:					
Anatomy	1 b	22	66	88	23
Anatomy	2 c	11	66	77	12
Anatomy	3 c	22	33	55	18
Totals		167	684	851	146
Summer term:					
Anatomy	3 a	24	72	96	7
Anatomy	3 b	24	72	96	7
Anatomy	3 c	24	36	60	6
Totals		239	864	1,103	166

Further time is required to prepare gross and microscopic material for laboratory use.

During the year two illustrated lectures on anatomy and poultry diseases were given at the poultry round-up, one lecture before the Society of Comparative Medicine and one at the banquet of the Battle Creek Poultry Association. Solicitation for the preparation of articles dealing with the diseases of poultry have come to me from a poultry journal but there has not been time available to comply with the request.

The work of the department warrants the services of an assistant on full time. Further the department needs less intensive quarters. The work in microscopy has been crowded since its inception. Since the laboratory for gross anatomy has been used as an embalming room, storage room and for class work in dissection, although the room is not large enough for any one of the uses to which it is put, the triple use renders it even a dangerous place for some students to occupy, particularly those with weak eyes and irritated throats and a disagreeable one to all because of a formalin saturated atmosphere. Considerable space should be allotted to the display of museum material already stored away and to the accumulating of specimens which pertain to the proper presentation of anatomical subjects at present inaccessable. We hope these conditions may be remedied in the near future.

Yours truly,
F. W. CHAMBERLAIN,
Associate Professor of Anatomy.

East Lansing, Mich., June 30, 1916.

REPORT OF DEPARTMENT OF BACTERIOLOGY AND HYGIENE.

President F. S. Kedzie, College:

Dear Sir—I have the pleasure to report to you on those phases of the departmental work for the year other than experimental and extensional. Changes in the teaching staff involve only the addition of Mr. L. C. Ludlum who comes to us from the University of Michigan to take up the work previously carried on by Dr. Himmelberger. Mr. Ludlum had charge of the class in pathogenic bacteriology and immunity and demonstrated marked ability in handling the students and in interesting them in the work. He also conducted in a satisfactory manner one section in Bacteriology 1c during the spring term, an arrangement made necessary by a conflict in my schedule. I have taken charge of both classes in sanitary science, given to the men in the fall term and to the women in the spring term, while Miss Northrup has taken on new courses in laboratory instruction for the engineers in the winter and spring terms. Mr. Brown was kind enough to take charge of one section in Bacteriology 1a in the fall term because of a conflict in my schedule. He has also directed the research and major studies for the M. S. degree of Mr. F. O. Ockerblad who received the degree in June. His thesis, "Viability of *Pseudomonus radicicola* under aerobic and partial anaerobic conditions," records a very interesting and valuable series of experiments. Mr. Morgan has supervised the major work of Mr. O. M. Gruzit in Soil Bacteriology. The degree of M. S. was granted in June. His thesis, "The effect of some acids, alkalis and inorganic salts in soil bacteria in soil solution" is a valuable contribution to the soil solution studies. Mr. Cooledge has maintained his former enviable reputation as a teacher of Dairy Bacteriology in the courses for the short course students in Dairy Hygiene for the veterinary students and in connection with the laboratory work of Market Milk, Dairy 4. There is an increased demand for additional courses in Dairy Bacteriology on the part of the undergraduates and graduates, but we are already under the necessity of using the new Dairy Building for part of this instruction although the room and facilities are not adapted to our needs. Mr. Cooledge has had a number of students taking advanced courses in Dairy Bacteriology during the year. One of these men, Mr. I. F. Huddleson, is completing his major for the M. S. this summer. His work deals with the effect of the milk in bovine infectious abortion on experimental animals.

During the past college year, the 1915 summer school inclusive, 224 students have taken bacteriological laboratory work. They are distributed according to courses as follows:

Courses	2	3	4	8	11	12	17	19	23	23a
Number in course	115	42	23	6	2	4	7	10	12	3

Courses 8, 11 and 12 are graduate courses and have been fairly well represented during the past two years, there having been a total of 14 in 1914-15 and 12 in 1915-16. Courses 23 and 23a are new courses designed for junior and senior engineering students who wish to specialize in sanitary engineering subjects. They were elected during the regular scheduled terms, however, by sophomore engineers. In the spring term senior engineers were allowed to substitute credits obtained in Course 23 for credits unobtainable in engineering subjects on account of the Engineering Building fire; seven men took advantage of this course.

Course 2, the beginning laboratory course, has been crowded nearly every term for the past two years, the other laboratory courses have been correspondingly well attended and during the coming year Course 2 is required of sophomore women in the winter term; hence there is a pressing need for more laboratory room. This situation will be taken care of this summer by the addition of a duplicate set of lockers throughout the laboratory. Courses 3 and 4 will then be required to meet at definite hours for laboratory work instead of electing any 8 hours during the week at the convenience of the student as heretofore. This will be a radical departure from the past method of conducting the laboratory courses in this laboratory and the coming year or years will give evidence as to the practicability of this arrangement, not merely from the standpoint of the mechanical efficiency of grinding out students with great rapidity, but from that of the quality of the product. It will be our endeavor to meet these changed conditions so that the student will not lose by this innovation. It has always been the aim of our laboratory instruction to train and to educate by personal contact and supervision and by the selection of a type of laboratory exercises that require cerebral as well as manual effort. Our new laboratory guide is proving helpful.

The following table shows the number of students registered in the various courses during the year 1915-1916:

Number of course.	Fall.	Winter.	Spring.	Summer, 1915.		Total for year.
1a	326	....	....	9	335	919
1b	....	291	....	4	295	
1c	....	....	285	4	289	
2	39	32	32	12	....	115
3	12	20	9	1	....	42
4	3	9	10	1	....	23
8	1	2	3	....	....	6
11	....	....	1	1	....	2
12	1	1	1	1	....	4
13	50	....	1	....	....	51
14	....	....	25	....	....	25
17	....	7	....	....	....	7
19	....	10	....	....	....	10
23	....	5	*7	....	....	12
23a	....	....	3	....	....	3
Totals	432	377	317	33	....	1,219

Courses 16, 18, 20, 21 and 22 were transferred September 1, 1915, to the Pathology department.

*Course 23 was repeated in the spring term as an accommodation to senior engineering students desiring credits unobtainable in engineering subjects on account of the Engineering Building fire.

I take great pride in the spirit shown by the various workers in this laboratory in respect to their relation to the student applying for instruction. Our research men are very patient in the presence of the many inconveniences resulting from student demands. I am not ready to state that research suffers seriously by our arrangement, but it is clear to me that the student may be greatly benefited by association with the research men. I wish to especially commend the work of Miss Northrup and Mr. Kulp, who bear the brunt of the laboratory instruction, who have not the stimulus furnished by the opportunity for research and who face without murmur the prospect of a hundred per cent increase in number of students for the coming year with no additional instructors to assist them.

The health of the student body, entrusted rather loosely and indefinitely to our care, is a matter of much concern to us. Our annual reports to your esteemed predecessor indicate our ideas relative to the need of certain changes and to the nature of these changes as do also our correspondence with you in this connection. On March 15, 1916, a student was taken to one of the detention hospitals with scarlet fever. During the previous week we had detained three men with measles and German measles and during the subsequent period up to the first of May, 1916, we detained 14 cases on account of scarlet fever, 11 cases of measles, one case of mumps and one of small-pox. There was also one case of diphtheria in the household of a faculty member resident off the campus. By June 3, 1916, every case had been dismissed from the hospitals and there had been no fatalities nor any unusually serious complications. It became necessary for us to utilize a dwelling on the campus in addition to our four detention hospitals and to use the general hospital for convalescents, but *in all cases the students were cared for on the campus by the college authorities.* A considerable number of students were detained by the physician's order until a diagnosis could be made with accuracy, but little or no inconvenience was caused individuals and at no time was the student body alarmed nor was there ever any reason to feel that the conduct of classes should be discontinued. There was practically no evidence of the spread of any of the diseases at the College or in East Lansing, nearly all cases being primary in so far as this epidemic is concerned. Nearly every case occurred off the campus *and not in the dormitories.* At the time of the epidemic nearly all parts of the State were experiencing similar or worse situations. Our experiences differed from that of some others in that *we knew where our cases were* and *they were under our charge.*

If in any respect we were unprepared to meet the emergency it is to be hoped that the future will demonstrate that we are wise enough to profit by our experiences. The success of the campaign against this epidemic must be attributed to the wisdom of yourself in appreciating its seriousness and in, not only authorizing but in keeping in close touch with every detail of the execution of the plan. Your wisdom in appointing the health officer of East Lansing, Dr. O. H. Bruegel, to take charge is indicated by the results achieved which speak more forcefully than words. We are indebted also to Dr. H. W. Landon for his cooperation, to Miss Ketchum of the general hospital for her vigilance and willingness to take on extra burdens, to Mr. Penner for his loyalty in a delicate situation and finally to all the nurses who assisted in the work of eradication.

Trusting that you will realize that I appreciate your council, cooperation and assistance during the year, I am

Respectfully yours,
WARD GILTNER,
Professor of Bacteriology.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF BOTANY.

President F. S. Kedzie:

Dear Sir—I hand you herewith my report for the Botanical department for the fiscal year ending June 30th, 1916.

The personnel of the department has undergone little change except as to the graduate assistants. It consisted in the year just closed of the following:—Professor Ernst A. Bessey, Ph. D., Associate Professor Richard deZeeuw, Ph. D., Assistant Professor Henry T. Darlington, M. S.; Instructors, Miss Rose M. Taylor, M. A., Miss Bertha E. Thompson, M. A., George R. Johnstone, A. B., Edward F. Woodcock, M. A.; Graduate Assistants, Mancel T. Munn, B. S., Paul C. Kitchin, B. S. Besides these, George H. Coons, Ph. D., and Rufus P. Hibbard, Ph. D., Research Assistants respectively in Plant Pathology and Plant Physiology in the Botanical Division of the Experiment Station devoted approximately two-fifths of their time to teaching their respective subjects in this department. The departmental stenographer until December was Miss Allyce

Hatcher who resigned because of ill health, her successor being Miss Catherine Trebilcock.

Miss Taylor was absent from College until November 1st, having spent three months on a collecting trip in Washington in company with Professor and Mrs. C. F. Kauffman of the University of Michigan. She obtained a large amount of very valuable material for class work in plant pathology. Owing to ill health brought on by overwork Miss Thompson was granted a leave of absence from January 1st to August 31st. Her place was filled for the winter and spring terms by Mr. Kitchin who was made a full-time instructor for this period.

Owing to changes in the courses of study of the Agricultural and Home Economics divisions respectively there was a large falling off in the number of lower classmen in botany. Beginning with last fall term, botany was no longer required for freshmen in the Home Economics course which caused a falling off of about 100 students in Botany 1a, 2a, and 3a. Beginning with the freshmen class in the fall term of 1914 all the required botany was given in the freshman year, instead of part in the winter term of the sophomore year. As a result Botany 4 was not given last winter term, causing a drop on that account of about 175 more.

The numbers of students for the different terms were as follows:

Summer term	11
Fall term.	
Freshman botany	267
Other undergraduate subjects	156
Post gradutes (major)	5
Short course	54
	482
Winter term.	
Freshman botany	256
Other undergraduate subjects	84
Post graduate (major	6
Short course	25
	371
Spring term.	
Freshman botany	232
Other undergraduate subjects	55
Post graduates (major)	5
	292

In this computation a student is counted but once for each course, even where his lecture and laboratory work are given by different instructors.

A subject like botany in which instruction consists of lectures and laboratory work requiring a considerable amount of special apparatus and individual supervision demands a larger number of instructors than some of the non-laboratory subjects. This is true because of the smaller sections that one person can handle. Thus in botany a laboratory section of twenty-four can be and is handled by one instructor, but this is too large for the best interests of the student. Furthermore, an instructor properly trained to handle such a section actually costs more than for a similar grade of work in a non-laboratory course. These factors make teaching in a laboratory subject much more expensive than for other subjects. I have calculated the teaching cost per student per term in the past year to have been as follows: fall term, $8.85; winter term, $12.05; spring term, $12.91.

The average number of teaching hours per full time instructor was about 18 per week; varying from 20 to 21 in the fall term to 15 to 17 in the spring term. Experience has shown that another hour's work is required in preparation of the laboratory material, correcting papers, etc., for every hour spent in teaching. Thus the actual average time given to teaching and the work connected with it has been about 36 hours per week. The result is that the instructors have difficulty to find enough time for the reading of current botanical literature and individual study that are necessary to keep them up to date in the subject.

In December I attended the joint meeting of the National and the Michigan Potato ,Association, delivering an address entitled "Seed Potatoes and Potato Diseases." In March I attended the meeting of the Michigan Academy of Science, of which I was President, and gave the presidential address, "The Sexual Cycle in Plants" as well as a paper entitled "A Harmonic Theory of Nuclear Action." I also attended the Biological Conference of the Schoolmasters' Club, discussing the report on science teaching in secondary schools.

Early in September, 1915, Assistant Professor Darlington made a walking trip for the purpose of collecting specimens for the herbarium and plants for the Botanical Garden. He walked from Kalamazoo to Allegan, Holland to Muskegon. At the latter point I joined him and we walked to Casnovia, Newaygo, Howard City and part of the distance to Big Rapids. Besides this several local trips were made in the vicinity of the College.

Chiefly through the efforts of Professor Darlington the Botanical Garden is being brought back to its former position as representing as far as possible the Michigan Flora. Thanks to the wet summer of 1915 the inadequate water supply of the garden was not felt as in previous years. This year a new connection has improved the supply. The larger lily pond was fixed up so as to prevent musk rat injury which had been very serious recently. A careful survey of the garden was made by Professor Darlington, who is a trained surveyor, and a map prepared. He has also reorganized the methods of keeping track of the plants in the beds.

The herbarium has received the duplicates of the very valuable collection of plants made by Mr. C. K. Dodge of Port Huron, who knows the flora of Michigan better, probably, than any other living man. These have been mounted and placed in the herbarium.

As usual the department has prepared and sold at cost, for the use of high schools and others interested, the following collections: (1) fifty important Michigan plant diseases; (2) one hundred kinds of seeds, chiefly those found as contamination in seed sold in Michigan; (3) twenty-five specimens of common weeds, mounted with stiff cardboard back and transparent cover. The time and labor expended in the preparation of these are well spent as a contribution to the College's educational work in the State.

The graduate students who have been majoring in botany have been given practical problems to work out for their investigational work. These have been as follows: R. W. Goss, "The Fusarium Wilt of the Potato"; S. P. Doolittle, "Cucumber Scab"; W. S. Beach, "The Fusarium Wilt of China Aster"; G. R. Gage, "Cultural Experiments with Rust"; L. J. Krakover, "A Macrosporium Leaf-spot Disease of Clover." At present M. T. Munn has nearly completed his work on a problem begun at the New York Agricultural Experiment Station on "Neck-rot of Onions." As a minor thesis problem Mr. Elmer Brandes worked on the Marsonina disease of lettuce. Other graduate problems undertaken but not completed on account of the students leaving college for other positions were the Macrosporium Leaf-spot of Melons, and the Septoria Leaf-spot of Lettuce. As minor problems in plant physiology Mr. Harrington worked on the determination of osmotic pressures in plant pulps by the freezing point method and Mr. O. M. Gruzit on the effect of deficiency of certain salts on the photosynthetic and other processes of plants.

As in previous years the organization of advanced students in botany known as the Botanical Seminar held its regular bi-weekly meetings. Examinations were held for admission to the organization, these being on invitation and limited to advanced students whose previous record in botany was good. Following the precedent of the two previous years a prominent botanist was brought in from outside to give a public address. This year Dr. William Crocker, Professor of Plant Physiology at the University of Chicago, spoke on "The History of our Present Knowledge of Plant Nutrition."

I must call attention to the crowded condition of the building and to the lack of adequate greenhouse space. The proposition made several times but not yet acted upon, to raise the roof so as to make a complete third floor, would add nearly 30 per cent to the available laboratory space and provide a laboratory for advanced students where they would be free from interruption by freshmen.

Respectfully,
ERNST A. BESSEY,
Professor of Botany.

East Lansing, Mich., June 30, 1916.

President F. S. Kedzie:

Dear Sir—I transmit herewith, as my report to the State Board of Agriculture on the work of the Seed Laboratory, the accompanying report by Miss Bertha A. Hollister, the State Seed Analyst.

Very respectfully,
ERNST A. BESSEY,
In charge of Seed Laboratory.

Dr. E. A. Bessey, East Lansing, Mich.:

Dear Sir—I have the honor to submit to you the report of the work done by the Seed Laboratory from July 1, 1915 to June 30, 1916.

Yours very truly,
BERTHA A. HOLLISTER,
State Seed Analyst.

East Lansing, Mich., June 30, 1916.

REPORT OF SEED ANALYSIS.

July 1, 1915 to June 30, 1916.

Owing to the adverse weather conditions of last year, the crops in many parts of the country were almost a total failure. The effect upon the seed business was very marked. The seed crop was very short, and most of the seed grown in this country was of very poor color, and somewhat shrunken. A great deal of seed was imported from France. This seed was bright and plump, but nearly all of it contained dodder. It was nearly always possible to tell whether or not the seed had been imported—as it usually contained weed seeds which are not found in seed grown in this country.

It was necessary to write to the dealers outside of the State about the labels which they put on seed shipped into Michigan. The Milwaukee Seed Co., of Milwaukee, Wisconsin, placed upon their labels the following legend: "Over 99½% pure from weed seeds"—varying the percentage to suit the occasion. This was literally true in every case which came to my notice, but an analysis of the seed showed it to be from one to three per cent lower in actual purity. Dealers in the State were informed that seed so labeled was in violation of the law. The dealers all bought this seed in good faith, thinking that it was high grade seed. They all paid a higher price for it than they should have paid for the quality they obtained. I notified the company that they would have to employ different methods when selling seed in Michigan. With one exception the dealers were glad to place the correct analysis upon their seed.

The four men who are collecting samples of fertilizer and feed for Mr. Patten, the Experiment Station Chemist, were appointed deputy seed inspectors, and acting in that capacity, reached a great many of the dealers.

The personnel of the Laboratory has undergone a change. Miss Madison, who was with me last year, left in February, to be married, and her place was taken by Miss Louise Mertes, of Traverse City.

The equipment of the Laboratory is essentially the same as last year, with the addition of a set of pamphlet filing cases, for the bulletins, and a binocular dissecting microscope.

I made a trip to Columbus, Ohio, during the Christmas holidays, to attend the meeting of the Association of Official Seed Analysts of North

America. Many instructive and interesting papers were presented at this meeting. The Association will meet in St. Paul in July. The change in time was made, because most of the Seed Analysts are exceedingly busy in the winter time. The latter part of July is not such a busy time for us, and therefore we hope to have a larger attendance. I expect to be present at this meeting.

The total number of samples tested during the year was 1,291, a somewhat smaller number than were tested last year. Of this number 43 were condemned on account of Canada thistle, or dodder, or both.

The following table shows the number of samples of each kind of seed tested:

To June 25th, 1916:

SEED TESTED.

	Unofficial.	Official.	Condemned.
Red Clover	727	15	31
Alsike Clover	152	6	6
Timothy	90	10	2
Alfalfa	58	2	
Sweet Clover	22	1	
White Clover	12	1	
Alsike Clover and Timothy	9	1	
Alsike and Red Clover	3		1
Red Clover and Timothy	2		1
Buckwheat	6		
Flax	2		
Oats	17		
Wheat	2		
Rape	8		
Redtop	13		
Canada Blue Grass	10		
Kentucky Blue Grass	11		
Orchard Grass	3		
Vetch	9		
Sudan Grass	3		
Red Fescue	5		
Creeping Bent	5		
Rye and Vetch	2		
Rhode Island Bent	3		
Perennial Rye Grass	7		
Lawn Grass	17	1	
Italian Rye Grass	2		
Bromus inermis	1		
Mixture	9		2
Cane	1		
Barley	3		
Rye	2		
Millet	10		
Wood Meadow Grass	1		
Crested Dog's-tall	1		

The following list shows the weeds found this past year, with the number of samples in which they occurred. The commercial seeds present as foreign seeds are included in this list. It shows an increase of thirty-five varieties over last year.

Acalypha virginica, Three-seeded Mercury	22
Achillea millefolium, Yarrow	44
Agropyron sp., Wheat Grass	2
Agrostemma githago, Corn Cockle	6

Agrostis sp., Redtop	99
Aira caespitosa, Wavy Hair Grass	3
Aira sp., Hair Grass	1
Alopecurus geniculatus, Marsh Foxtail	1
Alsine media, Common Chickweed	18
Amaranthus blitoides, Prostrate Amaranth	30
Amaranthus graecizans, Tumble-weed	19
Amaranthus hybridus, Slender Pigweed	1
Amaranthus sp., Pigweed	4
Ambrosia elatior, Ragweed	391
Anagallis arvensis, Red Pimpernel	4
Anthemis arvensis, Corn Camomile	8
Anthemis cotula, Dog's Fennel	70
Anthoxanthum odoratum, Sweet Vernal Grass	4
Anthyllis vulneraria, Kidney Vetch	2
Apargia autumnale, Fall Dandelion	3
Apera spica-venti, Silky Bent Grass	2
Arenaria serpyllifolia, Thyme-leaved Sandwort	18
Arrhenatherum elatior, Oat Grass	2
Artemisia biennis, Biennial Wormwood	2
Atriplex patula, Spreading Orache	13
Atriplex sp., Saltbush	5
Avena caryophyllea	1
Avena fatua, Wild Oats	6
Avena praecox	5
Avena sativa, Oats	7
Avena sp.	1
Barbarea barbarea, Yellow Rocket	2
Berteroa incana, Hoary Alyssum	1
Brassica arvensis, Charlock	14
Brassica juncea, Indian Mustard	2
Brassica napus, Rape	1
Brassica nigra, Black Mustard	16
Brassica sp., Mustard	2
Bromus hordeaceus, Soft Chess	4
Bromus inermis, Beardless Brome Grass	1
Bromus racemosus, Smooth Brome Grass	1
Bromus secalinus, Cheat	10
Bromus sp.	4
Bursa bursa pastoris, Shepherd's Purse	44
Camelina microcarpa, Small-seeded False Flax	51
Camelina sativa, Large-seeded False Flax	5
Campanulaceae	1
Capriola dactylon, Bermuda Grass	2
Carex spp., Sedge	57
Caucalis nodosa, Knotted Hedge Parsley	1
Cenchrus carolinianus, Sand Bur	2
Centaurea cyanus, Star Thistle	3
Centaurea picris, Russian Knapweed	2
Cerastium vulgatum, Mouse-ear Chickweed	113
Chaetochloa glauca, Yellow Foxtail	32

Chaetochloa italica, Millet	22
Chaetochloa viridis, Green Foxtail—Pigeon Grass	585
Cheirinia cheiranthoides, Worm-seed Mustard	10
Chenopodium album, Lamb's Quarters	429
Chenopodium hybridum, Maple-leaved Goosefoot	1
Chenopodium murale, Nettle-leaved Goosefoot	1
Chenopodium polyspermum, Many-seeded Goosefoot	1
Chenopodium sp.	1
Chrysanthemum leucanthemum, Ox-eye Daisy	7
Cichorium intybus, Chicory	2
Cirsium arvense, Canada Thistle	96
Cirsium lanceolatum, Bull Thistle	7
Compositae	8
Conringia orientalis, Hare's-ear Mustard	2
Coronilla sp., Ax-seed	2
Crepis virens, Hawk's-beard	1
Crotolaria sp., Rattlebox	3
Cruciferae	3
Cuscuta arvensis, Field Dodder	35
Cuscuta epithymum, Clover Dodder	1
Cuscuta indecora, Large-seeded Alfalfa Dodder	14
Cynosurus cristatus, Crested Dog's Tail	8
Dactylis glomerata, Orchard Grass	13
Daucus carota, Wild Carrot	36
Echinochloa crus-galli, Barnyard Grass	108
Eleocharis obtusa, Blunt Spike Rush	4
Eleocharis ovata, Ovoid Spike Rush	3
Erechtites hieracifolia, Fireweed	2
Ergot	3
Eruca eruca, Rocquette	3
Erysimum officinale, Hedge Mustard	2
Euphorbia preslii, Upright Spotted Spurge	2
Euphorbia sp., Spurge	4
Fagopyrum esculentum, Buckwheat	3
Festuca elatior, Meadow Fescue	8
Festuca heterophylla, Fine-leaved Fescue	7
Festuca myuros, Rat's-tail Fescue	12
Festuca ovina, Sheep's Fescue	1
Festuca rubra, Red Fescue	4
Galium aparine, Cleavers	2
Geranium carolinianum, Carolina Crane's Bill	1
Geranium dissectum, Cut-leaved Crane's-bill	8
Geranium sp.	2
Gramineae, Grass	30
Grindelia squarrosa, Gum-weed	7
Hedeoma pulegioides, Pennyroyal	4
Helianthus annuus, Sunflower	2
Hibiscus trionum, Bladder Ketmia	1
Hieracium aurantiacum, Orange Hawkweed	2
Holcus halepensis, Johnson Grass	1
Hordeum vulgare, Barley	10

Hosackia americana, Prairie Bird's-foot Trefoil	1
Hypericum perforatum, St. John's Wort	4
Hypochaeris radicata, Cat's-ear	11
Iva xanthiifolia, Marsh Elder	5
Juncus sp., Rush	37
Juncoides sp., Wood Rush	3
Koellia flexuosa, Narrow-leaved Mountain mint	14
Labiatae, Mint	7
Lactuca scariola, Prickly Lettuce	3
Lactuca sp., Lettuce	1
Lappula lappula, Stickseed	1
Lapsana communis, Nipplewort	10
Legouzia perfoliata, Venus' Looking Glass	1
Leguminosae	3
Leontodon taraxacum, Dandelion	3
Lepidium campestre, Field Peppergrass	19
Lepidium spp. (apetalum and virginicum), Peppergrass	81
Leptilon sp., Fleabane, Horseweed	10
Lithospermum arvense, Corn Gromwell	3
Linum usitatissimum, Flax	1
Lobelia sp.	3
Lolium italicum, Italian Rye Grass	2
Lolium perenne, English Rye Grass	17
Lotus corniculatus, Bird's-foot Trefoil	16
Lychnis alba, White Campion	5
Lycopus sp., Bugle Weed	19
Malva rotundifolia, Running Mallow	18
Medicago lupulina, Black Medick	60
Medicago sativa, Alfalfa	160
Melilotus alba, White Blossom Sweet Clover	72
Melilotus indica, Y. B. Annual Sweet Clover	3
Melilotus officinalis, Y. B. Biennial Sweet Clover	11
Milium effusum, Tall Millet Grass	3
Myosotis arvensis, Forget-me-not	1
Nepeta cataria, Catnip	32
Neslia paniculata, Ball Mustard	1
Norta altissima, Tall Mustard	9
Norta irio	1
Notholcus lanatus, Velvet Grass	25
Oenothera biennis, Evening Primrose	81
Ornithopus sativus, Serradella	1
Oxalis stricta, Wood Sorrel	2
Panicularia canadensis, Rattlesnake Grass	1
Panicularia fluitans, Floating Manna Grass	1
Panicularia nervata, Nerved Manna Grass	13
Panicum capillare, Witch Grass	101
Panicum lanuginosum, Wooly Panicum	13
Panicum virgatum, Switch Grass	3
Panicum miliaceum, Millet	1
Panicum sp.	3
Papaver sp., Poppy	3

Paspalum sp.	2
Persicaria aviculare, Knotweed	14
Persicaria hydropiper, Smartweed	5
Persicaria persicaria, Lady's Thumb	156
Phleum pratense, Timothy	640
Picris echioides, Ox-tongue	3
Picris hieracioides, Hawkweed Picris	2
Plantago aristata, Bracted Plantain	10
Plantago lanceolata, Buckhorn	531
Plantago major, Broad-leaved Plantain	101
Plantago rugelii, Rugel's Plantain	286
Poe annua, Annual Spear Grass	3
Poa compressa, Canada Blue Grass	23
Poa nemoralis, Wood Meadow Grass	7
Poa pratensis, Kentucky Blue Grass	35
Poa sp.	160
Portulaca oleracea, Purslane	1
Potentilla spp., Five Finger Cinquefoil	167
Prunella vulgaris, Heal-all	26
Ranunculus sp., Buttercup	6
Rubus sp.	1
Rudbeckia hirta, Brown-eyed Susan	13
Rumex acetosa, Sour Dock	6
Rumex acetosella, Sheep Sorrel	281
Rumex crispus, Curled Dock	292
Rumex obtusifolius, Bitter Dock	1
Rumex sp., Dock	60
Salsola pestifer, Russian Thistle	44
Scirpus, Club Rush	9
Scrophularia sp., Figwort	2
Secale cereale, Rye	8
Sherardia arvensis, Blue Field Madder	8
Sida spinosa, Prickly Sida	2
Silene antirrhina, Sleepy Catchfly	1
Silene dichotoma, Forked Catchfly	9
Silene noctiflora, Night Flowering Catchfly	301
Silene sp.	11
Solanum nigrum, Black Nightshade	18
Sonchus arvensis, Sow Thistle	1
Sonchus asper, Spiny Sow Thistle	8
Spergula arvensis, Spurry	5
Sporobolus sp., Rush Grass	7
Stipa sp.	1
Syntherisma ischaemum, Small Crab Grass	93
Syntherisma sanguinale, Large Crab Grass	21
Sudan Grass	3
Teucrium canadense, Wood Sage	1
Thlaspi arvense, Penny Cress	6
Tiniaria convolvulus, Wild Buckwheat	10
Trifolium hybridum, Alsike Clover	753
Trifolium incarnatum, Crimson Clover	3

Trifolium pratense, Red Clover	233
Trifolium procumbens, Hop Clover	10
Trifolium repens, White Clover	478
Trifolium spp.	7
Trisetum flavescens, Yellow False Oats	2
Triticum aestivum, Wheat	21
Umbelliferae	2
Undetermined	22
Verbascum blattaria, Moth Mullein	10
Verbena spp., Vervain	22
Vervonica arvensis, Wall Speedwell	19
Vicia hirsuta, Wild Vetch	1
Vicia sativa, Spring Vetch	1
Vicia sp.	1

REPORT OF THE DEPARTMENT OF ENGLISH AND MODERN LANGUAGES.

President Frank S. Kedzie, College:

Dear Sir—I have the honor to submit my fourth annual report for the Department of English and Modern Languages. This report covers the year ending June 30, 1916.

The enrollment for the year, exclusive of short courses, was as follows:

	English.	German.	French.	Total.
Summer term, 1915	18			18
Fall term, 1915	776	58	101	935
Winter term, 1916	838	50	79	967
Spring term, 1916	736	40	62	838
Totals	2,368	148	242	2,758

The teaching staff for the year just closing is as follows:

W. W. Johnston, Professor of English and Modern Languages.
Egbert S. King, Assistant Professor of Public Speaking.
Milton Simpson, Assistant Professor of English.
Ernst G. Fischer, Assistant Professor of German.
C. B. Mitchell, Assistant Professor of Public Speaking.
Norma L. Gilchrist, L. B. Mayne, J. Q. Owen, J. B. Hasselman, and F. L. Schneider, Instructors in English.
C. C. Armstrong, Instructor in English and Public Speaking.
Mrs. Antoinette C. Robson, Instructor in French and German.
L. C. Hughes, Instructor in French.

Three of the instructors named above have been members of the department for but one year. Mr. Schneider fills the place held last year by Mr. C. A. Fleming, who resigned to accept a scholarship in the University of Michigan; Mr. Hasselman succeeds Mr. Stepanek, who accepted a very attractive offer from the high school of St. Louis, Missouri; Mr. Hughes takes the place held by Miss Dora von Walthausen, who was on leave of absence last year, and whose place was filled temporarily by Miss Mary F. Howes. Miss von Walthausen having resigned last summer to become the wife of Mr. R. P. Hibbard, Research Assistant in Plant Physiology, Mr. Hughes was selected to fill her place permanently.

I am sorry to announce the resignation of Assistant Professor Milton Simpson and Mr. F. L. Schneider. Advised by his physician that Mrs. Simpson should not remain permanently in as damp a climate as that of Michigan, Mr. Simpson accepted an attractive offer of an associate professorship in Whitman College, Walla Walla, Washington. During his five years here Mr. Simpson has made a name as one of the able men of the institution; the loss of so strong a man will be severely felt by the Department of English. Mr. Schneider resigned to accept an instructorship in the University of Michigan. As Mr. Schneider, during his year of service here, has proved himself to be a valuable instructor, and I sincerely regret that we were unable to keep him.

As I have in previous reports called attention rather specifically to several important features of the departmental work, the departmental policy and the departmental methods, I shall here refer to some of the subjects treated in my reports for the preceding three years. In the report for 1913, I gave, among other items of information, (1) the chief divisions into which the work of the department falls (p. 92), (2) the course of study for the department and the manner in which it is determined (pp. 92 and 93), (3) the spirit of the department and the policy which I believe to be necessary for building up a department of English and Modern Languages adapted to this College (p. 94), and (4) the exceptional difficulties which the English teachers of the department are compelled to meet because the time allotted to required composition for agricultural students amounts to but two hours per term for one year (p. 95).

In the report for 1914 I gave, among other things, (1) a table showing the time relation of theme-reading to classroom instruction in English composition (pp. 127 and 128) and (2) the growing emphasis placed upon exposition in our work in English composition (p. 128).

In my report for 1915 I emphasized (1) our special classes for students deficient in grammar and spelling (p. 128); (2) our work in advanced composition (pp. 128 and 129); (3) our methods in public speaking (p. 129); (4) our methods in German and French (p. 129); (5) the development of interstate debating in the College (p. 130), and (6) the difficulties growing out of the fact that the department has not one classroom it can call its own (pp. 130 and 131). As the three annual reports to which I refer above cover much of the ground which should be familiar to those persons interested in the department, I shall omit, this year, all discussion of the methods or policies of the department.

The contests in which the department is directly interested are two—the tristate debate with Iowa State College and Purdue University, and the Eunomian-Holcad literary contest. We have withdrawn from all so-called oratorical contests.

The question for our tristate debate this year was "Resolved, That there should be vested in the National Government the exclusive right to manufacture and sell arms and munitions of war." The team which defended the affirmative of this question against the debaters from Iowa State College consisted of Mr. H. C. Huebner, Mr. H. H. Fuller, and Mr. L. S. Wells. The team which went to Purdue University to support the negative against Purdue's affirmative team consisted of Mr. H. M. King, Mr. H. C. Rather, and Mr. B. W. Bellinger. Our alternate was Mr. A. G. Kettunen. This year we lost both debates.

Two unusual features of the Eunomian-Holcad contest this year were the winning of the three highest prizes by one contestant and the winning of four of the five prizes by poems. Previously no contestant had won more than one prize, stories had done as well as poems, and essays had taken good places. The results of this year's contest are: First prize $25.00, offered by the Eunomian Society, was won by R. S. Clark, '18e, for a poem entitled Rime of the Plowman. The second and third prizes, $5.00 and $3.00, both offered by the Holcad, were also won by Mr. Clark, second prize for a poem entitled Johnny on Memorial Day, third prize for the poem Johnny Raves on Springtime Joys. The fourth prize, $2.00, offered by the Holcad, was won by Russell Waldo, '16a, for a poem entitled The Wood Thrush. The fifth prize, $1.00, offered by the Holcad, was won by Mary Warner, sp. h., for a story entitled The Deserter.

In closing I wish to thank the Board of Agriculture and the new administration for their very substantial and unfailing support of the department. I would likewise thank the members of my department, whose faithful and loyal efforts for the good of the Michigan Agricultural College have, I believe, been increasing steadily in efficiency. I would mention also those alumni associations that are raising a fund for the encouragement of the public speaking work of the department. The raising of this fund will do much to show our students that the graduates of M. A. C. recognize the importance of ability to speak in public. This will undoubtedly serve to improve the work which students do in our courses in public speaking.

Very respectfully submitted,
W. W. JOHNSTON,
Professor of English and Modern Languages.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF MATHEMATICS.

President F. S. Kedzie, College:

Dear Sir—I have the honor to submit for your consideration the following report on the work of the Department of Mathematics for the year, ending June 30, 1916:

During the year the teaching staff of the department was as follows:

L. C. Plant, Professor.

M. F. Johnson and L. C. Emmons, Assistant Professors.

S. E. Crowe, R. H. Reece, G. G. Speeker, W. M. Wible, E. C. Kiefer, and W. A. Reinert, Instructors.

The teaching staff has furthered the work so well begun last year, in holding themselves available to students for individual help throughout the day, in correcting problems and returning the same to students with helpful comments, and in helping to develop the course in agricultural mathematics.

It is gratifying to note the number of men in the department who take advantage of the vacation period to do graduate work in our leading universities. This advanced work not only broadens the teacher's training and makes him a more efficient teacher but it also makes him more sympathetic toward his students.

The total number of students taking mathematics during the year was 1,521, divided among the different terms as follows: fall 451; winter 589; spring 435; summer 46. The total number of class periods for the year was 427, divided among the terms as follows: fall 123; winter 139; spring 105; summer 60.

Respectfully submitted,
L. C. PLANT,
Professor of Mathematics.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF CHEMISTRY.

President Frank S. Kedzie, College:

Dear Sir—I have the honor to submit the following report on the work of the Department of Chemistry for the year ending June 30, 1916.

We have been able this year to make some changes in certain courses in order to better meet the needs of our students. For instance, the students of Home Economics have been segregated from the boys in General Chemistry, thereby allowing special emphasis to be placed on topics of particular interest to them. To further meet the needs of the Home Economics division a term course in Physiological Chemistry has been put in operation for the juniors. This course will be extended to a two term course next year.

Organic Chemistry has been substituted for the Metallurgical Analysis formerly given the freshmen engineers during the spring term. This course will bring all of our engineering students to the point where they may if they wish, elect the Engineering Chemistry group in the junior and senior years, preparing them more particularly for work of a chemical engineering nature.

These new courses, and the rapid increase in the number of students electing the advanced courses in chemistry, have worked to overtax our laboratory space and have necessitated using a laboratory in the Agricultural Building for one course during the past spring term. This crowded condition will, I fear, be even more pronounced this coming year.

Following is a table showing the number of students taking work in the department during the past year:

Summer Session, 1915.

	Registered.	Completed.
Metallurgical Analysis (Engineers)	3	3
Qualitative Analysis (Agriculturals)	3	3
Qualitative Analysis (Engineers)	1	1
Organic Chemistry (Agriculturals)	5	5
Organic Chemistry (Home Economics)	1	1
Quantitative Analysis (Agriculturals)	4	3
Quantitative Analysis (Home Economics)	2	2
General Chemistry (Agriculturals and Home Economics)	15	13

Fall Term, 1915.

	Registered.	Completed.
General Chemistry (Agricultural and Engineer)	396	318
Applied Engineering Chemistry (Engineer)	22	21
Quantitative Analysis (Agriculturals)	87	76
Quantitative Analysis (Home Economics)	8	8
Organic Chemistry (Home Economics)	73	57
Flour Chemistry (Agricultural and Home Economics)	1	1

Winter Term, 1916.

	Registered.	Completed.
Agricultural Chemistry (Agriculturals)	73	70
Qualitative Analysis (Agriculturals)	227	198
Applied Engineering Chemistry (Engineers)	9	9
Qualitative Analysis (Engineers)	115	97
Flour Chemistry (Agricultural and Home Economics)	3	3
General Chemistry (Home Economics)	116	97

Spring Term, 1916.

	Registered.	Completed.
Organic Chemistry (Engineers)	103	83
Organic Chemistry (Agriculturals)	232	186
Flour Chemistry (Agricultural and Home Economics)	1	1
Advanced Quantitative Analysis (Agricultural and Home Economics)	22	22
Physiological Chemistry (Vets.)	10	9
Physiological Chemistry (Home Economics)	19	16
Qualitative Analysis (Home Economics)	96	90
Physical Chemistry (Agricultural and Home Economics)	44	36

Besides the regular teaching work, analyses and baking tests have been made upon the wheat varieties grown by the experiment station in 1915, and a large number of samples of water, soil, feeds, ore, etc., sent in mostly by farmers of Michigan have been examined and reported upon.

In the matter of personnel of the department, we have been particularly fortunate. Every member of the staff has expressed deep interest in the department by hard, conscientious work. This has been especially important this year when the active head for so many years has been called to more strenuous duties and the many details of department administration have fallen upon other shoulders. I recognize fully that without the help of every member we could not possibly have had the successful year we have had, and I wish to express my great appreciation for the loyalty and support of all.

The teaching staff of the department for the past year has been as follows: Pres. F. S. Kedzie, A. J. Clark, R. C. Huston, B. E. Hartsuch, W. P. Wood, D. T. Ewing, D. C. Carpenter, H. L. Publow, C. D. Ball, K. G. Hancher, T. E. Friedemann, E. L. Underwood and Mabel Mosher.

Very respectfully submitted,
ARTHUR J. CLARK,
Professor of Chemistry.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF ZOOLOGY AND PHYSIOLOGY.

To the President:

Sir—I have the honor to submit the following report of the Department of Zoology and Physiology for the year ending June 30, 1916.

As noted in my report last year Instructor Scott was replaced by a new man and the choice fell on Joseph W. Stack, a graduate of Notre Dame University. Before the end of the fall term it became evident that more help would be necessary for the winter term and early in January permission was obtained for the employment of an additional instructor for the remainder of the year. Some difficulty was encountered in finding the proper person but late in January Mr. Stanard G. Bergquist, a graduate of the University of Michigan, was secured and rendered efficient service during the balance of the winter term and the entire spring term. Both Mr. Stack and Mr. Bergquist have been re-engaged for the coming year and it seems likely that no further changes in the teaching force of the department will be made.

During the present summer the head of the department will take a rest, but every other member of the teaching force will take post-graduate work, either in our own or some other college. Mr. Burt and Mr. Roseboom will take work in Chicago University, Mr. LeRoy and Mr. Bergquist in the University of Michigan at Ann Arbor, Mr. Conger at the Douglas Lake Biological Station of the University of Michigan, Mr. Stack at the Lake Laboratory of the University of Ohio at Cedar Point, Ohio, and Mr. Eastman in our own summer school at East Lansing. In addition Mr. Conger will take charge of the department and our summer school classes in elementary zoology and physiology until the end of July, when he will be relieved by Mr. LeRoy who will take charge for the rest of the vacation.

The regular work of the department has progressed satisfactorily during the year although the great size of some of the classes has taxed severely the capacity of the department. Indeed the laboratory work would have been seriously weakened in the winter and spring terms but for the fact that arrangements were made to utilize student assistants, mostly seniors, in several of the laboratories. Those employed in the winter term were S. H. Dwight, B. W. Householder, G. A. Newlon, J. W. Randall and R. H. Sill; in the spring term, S. H. Dwight, G. A. Newlon, R. H. Sill and H. Weckler. The three-fold division of the sophomore class for the courses in elementary zoology, physiology and geology has worked perfectly and doubtless will be continued in future years. The new elective course in elementary geology for engineers was given to a large class in the spring term and apparently filled a decided want. Still another course in geology, economic geology for engineers, has been authorized and will be given as soon as the conditions warrant it.

The following outline for the year indicates the number of classes and students handled by each member of the force. It should be borne in mind that in addition to the teaching hours indicated, each instructor spends at least as much time in the preparation and care of laboratory material and apparatus, while several members of the force are utilized in caring for the collections of the general museum for which no other provision is made.

Teaching Work of Department.

	Fall term, 1915.			Winter term, 1916.			Spring term, 1916.		
	Hours per week.	Number of classes.	Number of students.	Hours per week.	Number of classes.	Number of students.	Hours per week.	Number of oi classes.	Number of students.
Prof. W. B. Barrows	16	2	43	15	3	63	10	3	56
Asst. Prof. B. B. Roseboom	16	3	72	19	5	105	18	4	74
Asst. Prof. F. A. Burt	18	3	79	21	2	62	20	3	54
Inst. A. C. Conger	18	3	71	24	4	108	22	4	97
Inst. V. E. LeRoy	18	3	91	22	4	93	22	5	91
Inst. W. E. Eastman	19	5	128	24	5	102	22	4	68
Inst. J. W. Stack	19	4	104	23	5	131	21	5	89
Inst. S. G. Bergquist	....	....	....	22	6	144	20	4	55
Totals	124	23	588	170	34	808	155	32	584

MUSEUM.

The condition of the general museum remains about the same as last year, the lack of space preventing any general re-arrangement of the collections even had the time for such work been available. In point of fact, however, we are barely able to keep the specimens free from museum pests and the cases in a presentable condition for the public. Each year the museum is drawn upon more heavily for our own teaching purposes and almost every week parties of students from high schools and other educational institutions in neighboring cities come here to visit the museum and study the collections.

We have hundreds of duplicate specimens of various kinds, particularly of mounted birds, which should be made up into small circulating or loan collections and sent out to the schools of the State. At present most of these specimens are packed away in tin cases in attic or cellar, serving no useful purpose whatever. As soon as funds are available it is our intention to recommend a plan for an entire re-arrangement of our collections and the utilization of much of this duplicate material. Such a plan will involve the employment of at least one additional assistant who can give most of his time to museum work.

In February the Public Domain Commission requested the College to make an exhibit of museum specimens at the meeting of the Michigan Wild Life Conservation Association at Saginaw, February 23-26, and this was supplemented by similar requests from other organizations interested in these meetings. As a result the Department of Zoology prepared an exhibit of about one hundred and fifty birds, with descriptive labels, illustrating the common harmful and beneficial species found in this State. A member of the Zoological department was in attendance all through the convention and was able to give much information to visitors in regard to the natural history of the State and the work of the College.

The Harry K. Pomeroy collection of birds' eggs, mentioned in our last report, was safely transferred to the College last October and has been unpacked and arranged in a new case specially built for it at the expense of $160.00. This case replaces a smaller one, also filled with bird's eggs, which has been transferred temporarily to the Zoological Lecture-room. The Pomeroy collection contains upwards of three thousand specimens and doubtless is the finest single collection of eggs of foreign birds in Michigan.

Respectfully submitted,
WALTER B. BARROWS,
Professor of Zoology and Physiology and
Curator of the General Museum.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

President F. S. Kedzie:

Dear Sir—Following is a brief report of the work of the Department of Entomology for the year ending June 30, 1916.

The year just finished has passed without unusual development. Nine regular courses have been given besides the courses in the summer school —course five being repeated so that it runs throughout the year. Besides these regular courses, there were two short-courses in Agriculture. Also, instruction was given during the week known as "Bee-keepers' Week" to a good sized class of bee-keepers from Michigan and other parts of the U. S. and Canada. During the week of this school we were fortunate in securing the aid of three experts, Prof. Morley F. Pettit of Guelph, Provincial Apiarist of Ontario, Mr. Ira D. Bartlett of East Jordan, and Mr. David Running of Filion. During Round-up Week special attention was given to apiculture, the department being aided by Mr. Bartlett.

The inspection of apiaries has gone on as heretofore and a number of demonstrations in disease control have been held, but the efforts of one man are inadequate. It is impossible to visit more than a part of the apiaries where owners request advice in regard to disease, because one man can not possibly get to more than a small percentage of the apiaries.

Both American and European foul-brood are spreading over the State, the owners of the apiaries simply being unable to cope with the disease, because they are not familiar with the symptoms of the disease or with the proper treatment. A change in the law providing for deputy inspectors seems to be the only hope for the bee industry in our State.

Besides the courses enumerated, three short courses were given during the fall and winter, to students in general agriculture and in horticulture.

On July first, 1915, Mr. Don B. Whelan commenced work as Extension Specialist in the control of insect pests; since that time Mr. Whelan has devoted a little more than half his time to visiting places where the need has arisen and in giving aid to the farmers, fruit growers, millers, nursery men, mushroom growers, market gardeners, and in fact to people of any calling who may be dependent on agriculture for a living. His efforts have been met with appreciation and have resulted in bringing the department and the College in still closer touch with the people; furthermore, his visits have reminded many of our old friends of our readiness to aid wherever possible, besides directing many new friends to us.

Already the requests for aid and advice have increased as a result of Mr. Whelan's activities, as well as through the medium of our county agents.

Respectfully submitted,
R. H. PETTIT,
Professor of Entomology.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF HISTORY AND ECONOMICS.

To the President:

The following is the report of the Department of History and Economics for the year 1915-16.

Total number of enrollments in the department for the year equalled 1671, distributed as follows:

By terms: Fall, 738; Winter, 430; Spring, 432; Summer, 71.

By classes: Graduate, 25; Seniors, 380; Juniors, 422; Sophomores, 398; Freshmen, 355.

By subjects: History, 352; Economics, 1130; Political Science, 189.

Total number of hours taught during the year by members of the department are 2262, divided among the three terms as follows: Fall, 978; Winter, 480; Spring, 564; Summer, 240.

By subjects the number of recitation hours during the year equalled—in Economics, 1212; in History, 900; in Political Science, 240.

HANDLING OF CLASSES.

The department has experienced a repetition during the past year of the swollen classes upon which comment was made in our last report. While but two new and additional subjects were presented during the past year, an examination of the enrollments for the year just past shows an excess of 188 students over any previous registration of the department.

The purpose of introducing this comparison last year was to show the abnormal size to which many of our classes had grown, and to point the need of additional teachers if the subjects concerned were to be taught as efficiently as students at this College should be taught. The need along this line, which was pressing last year, has this year become imperative. Some classes numbered 90 and 100 enrollments. It is plain that classes of this size are unwieldy for teaching purposes.

NEW SUBJECTS.

During the past year the department has been intrusted by the faculty with the future teaching of two new and additional subjects of study—General Accounting and Farm Marketing. The former is in response to a wide spread demand for further training in the scientific analyzing of undertakings attempted for profit. The latter subject endeavors to present information with regard to the deservedly significant problem—the distribution of farm products. There seems to be a rapidly growing belief among the well informed that the distribution of farm products means fully as much to the farmer as their production. It would seem to be a foregone conclusion that investigation and experimentation therefore in this marketing realm would prove equally as useful to the farmer as investigation and experimentation has proven in the field of production.

The new Home Economics curriculum adopted last year, having now become operative throughout the entire four years of the college course, presents for teaching purposes in this department this year for the first time two additional subjects. There are the Principles of Sociology and a course in descriptive economics, entitled "The Elements of Economics." The first is elective, the second required, and both are full five hour per week studies.

SUMMER SESSION.

A unique experiment was tried during the Summer Session of 1916 in an endeavor to answer the wide-spread demand for scientific instruction in the subject of farm business. It was held that a somewhat popular but comprehensive treatment of this matter would prove attractive, not only to students but to practical people throughout the State, interested in these lines. The course was therefore gotten up according to a plan which gave two week presentations each to different phases of farm business—Cooperation, Marketing, and Farm Accounting—using specialists for each period of presentation. Unusual good fortune attended the College in securing these specialists, and a list of able men, including Professor Alex. Cance, Rural Economist at Amherst College, Dr. Edward Jones, Professor of Commerce and Administration at the University of Michigan, Dean J. A. Bexell, Professor of Commerce, Oregon Agricultural College, and R. V. Gunn, instructor in Farm Management at the University of Wisconsin, dealt with the different phases upon which they are specialists.

The experiment seems to have been a perfect success if the enthusiasm with which the courses were attended may be taken as a criterion. The regular enrollment of those taking the subject for credit was at all times in excess of forty, while on many occasions—as the result of visitors from some one or another of the summer conferences in progress here—as many as sixty or seventy students were in attendance.

SIDE ACTIVITIES.

The growth of the College in increased numbers of students and in variety and numbers of activities imposes constantly upon heads of departments the selective function of trying to tell how their undertakings may best be distributed. The head of this department for example, as chairman of the social committee has had to do with the supervision of approximately one hundred and fifty social events during the past year; as Secretary of the M. A. C. Book-buying Association he has performed the usual services going with such an office; as Lansing representative upon the Alumni Council he has attended many meetings of this organization; and he has served upon the customary number of general committees. He attended also the National Marketing and Rural Credit Conference in Chicago in December, and through the generosity of yourself and the State Board, the American Economic Association meeting at Washington also in December. One address was given by him at the M. A. C. alumni meeting in Washington during February, another at the State High School Teachers of Agriculture meeting in April, and another at the Summer School of Kalamazoo College in July. He was also one of the promoters of the regular winter meeting of the State Country Life Conference. These activities are mentioned as in no wise exceptional from the performance of all heads of departments, but merely as illustrative of a field of duties—which though desirable nevertheless detract from the time which teachers have for their regular business.

DIVISION OF DEPARTMENT.

The present report marks the end of a series of reports which was commenced with the establishment of a department of History and Economics in 1889. At the regular meeting of the State Board of Agriculture in June, action was taken whereby a separation was made in this department and a new department of Political Science and History and another of Economics were created. The well being of the group of subjects which had formerly been classed together under the title of History and Economics was in no respect advanced through continuing this association of well nigh thirty years. Economics, since 1889, has become more and more emphatically a science, and in more recent years—through the general interest which has developed in marketing, accounting and organization, an applied science. History, in the meantime, has undergone in the stirring events of the past two years an almost complete shifting of importance. It must certainly be taught from a different standpoint in the future than was formerly the case, and the interests of this subject and also of political science demand that they should have the exclusive time of a specialized department head. The Board upon this matter provided:

> "The President is authorized to arrange for the division of the Department of History and Economics. The Department of Economics to be established with Dr. W. O. Hedrick at its head, and including within it Assistant Professor Dunford, and an additional instructor; the Department of History and Political Science to be placed in charge of Prof. E. H. Ryder, assisted by Mrs. Hendrick as instructor."

and in harmony with this record the setting apart of Political Science and History and Economics has been finally accomplished to the entire satisfaction of all concerned.

The department has had faithful service from the members of its teaching force during this year as in times past, and pleasure is taken in acknowledging the efforts of Prof. Ryder, Mrs. Hendrick and Prof. Dunford, as the regular employees, and also of Mr. Paul Miller and Miss May Person, who were employed during a portion of the year.

Respectfully submitted,
WILBUR O. HEDRICK,
Professor of Economics.

East Lansing, Mich., June 30, 1916.

REPORT OF THE DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

The President, Michigan Agricultural College:

Sir—I am enclosing report of Sergeant P. J. Cross, U. S. Army, concerning period of training in the Military department, from the opening of the college year 1915-16, to January 26, 1916, the date of report of present Commandant for duty at this College.

At date of my report, the six freshman companies were drilling in the Armory in two sections, three companies, on Monday and Tuesday, three companies on Wednesday and Thursday. Satisfactory progress had been made in close order, even in spite of the limited space for such drill. All freshmen had one hour in theoretical work in classroom.

During the winter term, sophomores and juniors, were in theoretical instruction under senior instructors in classroom. Moss's Manual of Military Training, was used in this work.

During the spring term, all work was out of doors. This included close order work and ceremonies, such as parades, reviews, guard mounting etc.

The other practical work included outposts, advance and rear guards, also flank guards, marches and calisthenics.

The drill season closed with a field day on Decoration Day. This event was considered very successful and created satisfactory interest in the cadet regiment. Company "A," a junior company, under Cadet Captain E. W. Martin, won the competition; Company "K," under Cadet Captain F. A. Carlson, was second and Company "C," under Cadet Captain L. H. Gork, was third.

The competition included wall scaling, tug of war, company drills, manual of arms drill and company shooting. The wall scaling contests were especially interesting to spectators, and instructive to contestants.

The college year was completed June 13th, with a review of the corps of cadets by the commandant accompanied by Capt. Wells and Capt. Ragsdale, U. S. A. The regiment was paraded then by the Cadet Colonel C. N. Winston.

An innovation was tried out this spring term. Drill hour was changed from 4:30 to 5:30 p. m., to 7 to 8 a. m. The change was not considered very satisfactory and the drill hour will be as heretofore 4:30 to 5:30 p. m.

The greater part of the cadet officers were very satisfactory. The senior officers were chosen from the senior class by examinations, both theoretical and practical.

The new officers for 1916-17 were chosen in a similar manner, and it is believed that an exceptionally efficient selection has been made. Upon acceptance of the officers for the coming year it was announced by the Commandant that no one was wanted who was working for credits only. Those only were wanted who desired to progress in the military work and had the interest of the corps in view.

The prospect of an interesting year in the work is very good

Very respectfully,
IRA LONGANECKER,
1st Lieut. 22d U. S. Infantry,
Professor of Military Science and Tactics.

To the President, Michigan Agricultural College:

Sir—I have the honor to submit the following report covering the work in this department from the beginning of the college year 1915, to January 26, 1916.

1. Both the practical and theoretical courses of instruction were changed considerably at the beginning of the college year so as to conform to the requirements of the War Department; heretofore not more then one-half of the required subjects being covered. The revised course has also been made more attractive and instructive; not being the same old subjects term after term. The course now contains those subjects which any good citizen, who is a college graduate, should know.

2. Apparently from outward appearances, the interest displayed by the student body generally in the military work has been much more marked and noticeable during the last few years. This is probably due to a number of causes, but the work can, and will be made more attractive.

Aside from the military value, the drill is a good, clean, and healthful exercise, and the young men who have been taught to walk erect and expand their chests will have several years added to their lives. The instructors can give sound advice to their classes, and it is recommended that they do so whenever an occasion is presented. Of course it is understood that correct information and advice should be given; not information that is liable to create a wrong impression or ridicule.

3. The success of the college rifle team in winning the intercollegiate championship of the United States deserves special mention. The twelve students who were especially selected for their expertness in rifle shooting deserve commendation. These men worked exceptionally hard during the fall and winter terms; and during this time, they proved the fact that rifle shooting, is one of the most healthful exercises, and one of the most exacting sports in which a student may engage. It not only develops the muscles, eyes and nerves, but teaches how to co-ordinate the functions in unison and produce results which otherwise were impossible.

This phase of the military work could be greatly developed at a very small expense, and it would also increase the interest of the student body. A complete out-door target range should be provided, where shooting up to five and six hundred yards could be conducted.

As most of the ammunition would be provided by the Federal Government, the up-keep of the range would be very small.

There are a number of out-door matches in which students could compete. These would be shot under the rules of the National Rifle Association of America, and the prizes furnished by the same association free of charge.

4. The college band is now entering upon one of its most successful years, and under the efficient leadership of Professor A. J. Clark, will continue to be one of the most enjoyable organizations of the College.

Very respectfully,
P. J. CROSS,
Sergeant of Engineers, U. S. Army, Assistant.

East Lansing, Mich., June 30, 1916.

REPORT OF DEPARTMENT OF ATHLETICS.

To the President:

Dear Sir—I have the honor to submit the following report of the Department of Athletics for the year ending June 30, 1916.

It has been the aim of the department to induce as large a number of students as possible to take advantage of the helpful exercises and contests managed by this department. With the aim of general good to the whole student body we have encouraged all branches of intermural games and contests and the majority of the students attending school have benefited by them. A regular gymnasium class was held during the winter months and in spite of the limited apparatus and poor facilities much interest was shown and a large number of students attended regularly. One of our greatest needs has been a place, properly equipped for systematic exercise and games during the winter months and it is very encouraging to feel that inside of another year we will be able to move into such a place and furnish the students with the exercise which is so essential to the physical welfare of all.

Teams representing the College in the various competitive sports have acquitted themselves with much credit. This intercollegiate competition has encouraged loyalty to the College, gentlemanly conduct, and absolute fairness at all times.

One of our most important athletic events was the Interscholastic Track and Field Meet held here on June 10th. Over forty high schools throughout the State were represented and about three hundred promising college men visited our College. The meet was very successful, and it not only aids in inducing many desirable men to attend our College but it proves of infinite value in the way of advertising.

With the aid of the blanket tax the Athletic Association has been entirely self-supporting. The large number of men interested in athletic contests and reporting out for practice made it necessary for the employment of two assistant coaches during the football season and their expense was entirely borne by the association.

A great number of students have received athletic training during the past year and it is our aim to induce all of the boys to work for one of the athletic teams at least.

Respectfully submitted,
G. E. GAUTHIER,
Acting Director of Athletics.

East Lansing, Mich., June 30, 1816.

STATEMENT OF FUNDS.

	Receipts, June, 1916.	Disbursements, June, 1916.	Receipts, Sept. 1, '15 to June 30, '16.	Disbursements, Sept. 1, '15 to June 30, '16.
Gate receipts	$94 25		a$5,769 36	
Season tickets	4 00		186 00	
Guarantee	100 00	$175 00	b6,560 58	c$5,002 62
Student Fees	1 67		7,007 89	29 60
Salaries, Labor		451 75		3,327 15
Officiating		54 55		617 15
Travel		428 86		3,372 31
Office and General Supplies		890 15		4,010 12
Training table		427 40	161 00	1,729 14
Printing				175 73
Miscellaneous	23 65	150 60	66 02	904 30
	$223 57	$2,578 31	$19,750 85	$19,168 12
Balance beginning Sept. 1, 1915			866 70	
Balance on hand June 30, 1916				1,449 43
			$20,617 55	$20,617 55

A. Receipts, Football	$4,979 86
A. Receipts, Basketball	89 75
A. Receipts, Baseball	699 75
B. Guarantees, Football	$5,324 70
B. Guarantees, Basketball	500 88
B. Guarantees, Baseball	735 00
C. Guarantees, Football	$3,367 62
C. Guarantees, Basketball	600 00
C. Guarantees, Baseball	1,035 00

Total balance to credit of Athletic Association including balance of $725 in revolving fund, is $2,174.43.

M. A. C. ATHLETIC ASSOCIATION,
A. M. BROWN, Treasurer.

REPORT OF THE DEPARTMENT OF METEOROLOGY.

Dr. F. S. Kedzie, President, Michigan Agricultural College:

Dear Dr. Kedzie—I have the honor to make the following report concerning the work of this department for the year ending June 30, 1916.

Twenty students completed the regular course in meteorology during the fall term of 1915. As in years past the aim has been to give the students a good, practical knowledge of the subject.

In addition to the regular course a series of twenty lectures was given to the two-year short course men in the winter term.

Very respectfully,
D. A. SEELEY,
Instructor in Meteorology.

REPORT OF THE LIBRARIAN.

President F. S. Kedzie:

Dear Sir—I have the honor to present the following report on the library for the year ending June 30, 1916.

There have been added to the library during the year 2,659 bound volumes, of which 1,136 were purchases, 1,004 came by binding, and 519 were gifts.

Of unbound volumes and pamphlets 207 have been received, of which 9 were purchased. The remaining 198 were gifts to the library, and were acknowledged when received if the donor were known. We therefore omit individual mention.

We are indebted as follows for bound volumes:

Andrea, P. 1.
American Lumberman. 1.
American Veterinary Medical Association. 1
Alexander, Mrs. D. H. 1.
American Association for International Conciliation. 1
American Jewish Association. 1
Allen, A. S. 2
Association of Advertising Clubs of America. 2
Arkansas, State reports. 2
Advisory Commission, Finance Forum. 1
American Society of International Law. 2
Bleininger, C. V. 1
Baker, F. A. 1
Beal, Dr. W. J. 6
Byrum, E. E. 1
Beecher, L. Autobiography. 2 Donor unknown.
British Columbia, Agriculture Dept. 2
Baker, R. S. 1
Canada. 22
Carnegie Endowment for International Peace. 6
Colorado, State reports, 1
Connecticut, State reports. 2.
Chicago Association of Commerce. 1
Chemical Rubber Co. 1
Chicago, Lincoln Park Commissioners. 1
Conference of Governors, Proceedings. 1
California, State reports. 1
Cutler & Hammer Mfg. Co. 1
Carpenter, L. G. 2
Committee on Christian Education. 1
Dunning, Laurence E. 1
Detroit, Mich., Reports of the Comptroller. 5
——— Dudley Memorial volume.
Fischer, Prof. Ernst. 2
Fenton, F. R. 1
Gates, R. R. 1
Grisdale, J. H. 1
Gospel Trumpet Co. 4
Gardner, A. W. 1
Huntley, Florence. 1
Hartford Steam Boiler Co. 3
Holdsworth, Mrs. W. S. 3
Hueffer, F. M. 2
Henus, Max. 1
Iowa, State reports. 3
Illinois, State reports. 3
Interstate Cotton and Crushers Association. 1
Imperial Japanese Commission. 1
Japan Society. 2
Kansas, State reports. 4
Kentucky, State reports. 3
Kedzie, Mrs. George. 1

Kellogg, B. 1
Kennon, Geo. 1
Kidd, Gen. J. A. 1
Los Angeles, Cal. 4
Longmans, Green & Co. 1
Michigan, State reports. 67
Michigan Academy of Science. 1
Minnesota, State reports. 4
Massachusetts, State reports. 6
Missouri, State reports. 2
Montana, State reports. 7
Maine, State reports. 2
Macmillan, C. 2
Maxweiler, E. 1
Moss, F. J. 1
New York, State reports. 18
New York University. 1
New York City. 5
New York Stock exchange. 1
New Jersey, State reports. 15
Nebraska, State reports. 2
New Hampshire, State reports. 1
National Association of R. R. Commissioners. 7
North West Territories. 1
National Canners Association. 1
Oregon, State reports. 1
Pammel & Weed. 1
Prudential Insurance Co. 2
Parker, Sir Gilbert. 3
Proc. of the Conference of Farmers' Institutes and Short Course Workers on Permanent and Sanitary Farm Improvements. 1
Pennsylvania, State reports. 1
Revell Pub. Co. 1
Rand, A. 1
Smithsonian Institution. 4
Scriven, G. P. 1
South Australia. 1
San Diego, Cal. 1
Schaeffer, J. A. 1
Shoesmith, Prof. V. L. 1
Sturgis & Walter, Pub. 1
Trustees of the Mary Baker Eddy Fund. 10
Thompson, S. 7
University of Michigan. 2
U. S. Brewers' Association. 2
U. S. Supt. of Documents, 55
U. S. Dept. of Agriculture. 36
U. S. Census Bureau. 35
U. S. Civil Service Commission. 2
U. S. Navy Department. 3
U. S. Geological Survey. 7
U. S. Education Bureau. 5
U. S. Interstate Commerce Commission. 1
U. S. Land Office. 1
Universal Portland Cement Co. 5
Wisconsin, State reports. 1
Warren, F. H. 1
West Virginia, State reports. 1
Williams College. 1
Weems, J. B. 1

Miscellaneous, (Donors unknown) 57.

On our regular periodical subscription lists are 299 publications, American and foreign, of which the College purchases 256, and the Experiment Station 43. These periodicals are for the most part bound, and become a permanent and valuable part of the library.

We also receive a number of publications which are sent either as gifts, or in exchange for our own publications. The list follows:

Advocate of Peace.
Agricultural Digest.
Agricultural Gazette of Canada.
Agricultural Gazette of N. S. Wales.
Agricultural Review.
Allegan Gazette.
American Cheesemaker.
American Economist.
American Farming.
American Hereford Journal.
American Iron and Steel Institute, Bulletins.
American Issue.
American Lutheran Survey.
American Midland Naturalist.
American Miller.
American Poultry Advocate.

American Sheepbreeder.
American Swineherd.
American Thresherman.
Angora Journal.
Annals of the Missouri Botanic Gardens.
Australiasian.
Australian Museum, Records.
Bay City Times. *Daily.*
Bear Lake Beacon.
Belding Banner.
Berkshire World & Cornbelt Stockman.
Better Farming.
Better Fruit.
Big Four Poultry Journal.
Bi-Weekly Farm Bulletin.
Blue Valley Bulletin.
Boletin de Agricultura, Sao Paulo.
Boletin de Ministerio Agricultura.
Brooklyn Botanic Gardens. *Leaflets.*
Brownell Dairy Farmer.
Bulletin of the Grand Rapids Public Library.
Bulletin N. Y. Botanical Gardens.
Bulletin of the Pan-American Union.
Bulletin Boston Museum of Fine Arts.
California Academy of Science, Proceedings.
California Home and Farmer.
Canadian Forestry Journal.
Canadian Horticulturist.
Canal Record.
Carlisle Arrow.
Chicago Packer.
Christian Science Monitor.
Christian Science Sentinel.
Christian Science Journal.
Clinton Republican.
Cold.
Coldwater Republican.
Commerce Reports.
Commercial Fertilizer.
Comptes Rendus des Seances de l'Acad. d'Agri. de France.
Congressional Record.
Daily Drovers Journal & Stockman.
Dairy Record.
Dakota Farmer.
Daughters of the American Revolution Magazine.
Detroiter.
Duroc Bulletin.
East and West.
Edison Monthly.
Electric Traction.
Etude.
Farm Adviser.
Farm Engineering.
Farm Life.
Farm Machinery: Farm Power.
Farm Stock and Home.
Farm and Fireside.
Farm and Home.
Farm and Ranch Review.
Farmer and Breeder.
Farmers' Advocate and Home Journal.
Farmers' Advocate and Home Magazine.
Farmers' Guide.
Farmers' Wife.
Farming Business.
Field.
Field and Farm.
Flour and Feed.
Flour, Hay, Grain and Feed.
Fruit Belt.
Fruit Grower.
Fruitman and Gardener.
Gas Power.
Gleanings in Bee Culture.
Grand Rapids Herald.
Grange Forum.
Grape Belt.
Guernsey Breeders' Journal.
Hastings Banner.
Hastings Journal-Herald.
Hawaiian Forester.
Hoard's Dairyman.
Holstein-Friesian World.
Homestead.
Horsebreeder.
Horse World.
Horse Shoers' Journal.

Hospodar.
House and Garden.
Idaho Farmer.
Illinois Agriculturist.
Illuminating Engineer.
Imlay City Times.
Improvement Era.
Independent Farmer.
India, Agricultural Research Institute, Pusa.
India, Agricultural Journal.
India, Agricultural Research Institute, Pusa, Memoirs, Bacteriology Series, Botany Series, Chemical Series, Entomology Series.
Indian Farmer.
Indian's Friend.
Indicator.
Ingham County News.
Intercollegiate Socialist.
International Institute of Agriculture. Publications.
Jersey Bulletin.
Jewish Farmer.
Johns Hopkins University, Circulars.
Journal of Agricultural Research.
Journal of the American Bankers' Association.
Journal of the American Institute of Architects.
Journal of the Board of Agriculture & Fisheries. London.
Journal Cincinnati Society of Natural History.
Journal of the College of Agriculture, University of Tokio.
Journal of the College of Agriculture, Imperial University Sapporo.
Journal for experimentelle Landw. (Printed in Russian language).
Kalamazoo Gazette.
Kalamazoo Telegraph.
Kansas Farmer.
Kimball's Dairy Farmer.
Lister Institute of Preventive Medicine, Collected papers.
Lansing State Journal. *Daily.*
Lewiston Journal.
Liberty.
Lincoln Freie Presse.
Live Stock Report.
Louisiana Planter.
Manton Weekly Tribune.
Mark Lane Express.
Market Growers' Journal.
Menorah Journal.
Message of the East.
M. A. C. Record.
Michigan Farmer.
Michigan Mirror.
Midland Naturalist.
Midland Republican.
Milchwirtschaftliches Centralblatt.
Moderator-Topics.
Modern Gladiolus Grower.
Monthly Bulletin, California Commission of Horticulture.
Monthly Crop Report.
Monthly Review, United States Labor Bureau.
National Association of Corporation Schools, Bulletin.
National Daily.
National Farmer.
National Grange Monthly.
National Stockman and Farmer.
New York Meteorology. Draper's Hourly Readings.
New York Produce Review.
News-Palladium, Benton Harbor.
Nova Scotia Institute of Science, Proc. & Trans.
Nut Grower.
Official Gazette, United States Patent Office.
Ohio Farmer.
Ohio Journal of Science.
Oklahoma Farm Journal.
Orange Judd Farmer.
Oregon Farmer.
Osceola County Herald.
Our Dumb Animals.

Owosso Press American.
Pacific Daily Review.
Park and Cemetery.
Petoskey Independent Democrat.
Philippine Agricultural Review.
Philippine Agriculturist & Forester.
Poland China Journal.
Poona Agri. College, *Reprints.*
Poultry Life.
Poultry Pointers.
Poultry Tribune.
Practical Farmer.
Proceedings American Philosophical Society, Phil.
Public Health Reports, U. S. Marine Hospital.
Publicity Magazine.
Reclamation Record.
Reliable Poultry Journal.
Revista Industry Agricola de Tucuman.
Rhodesia Agricultural Journal.
Rockefeller Institute for Medical Research, Studies.
Rural New Yorker.
Saginaw Daily News.
St. Joseph Daily Press.
Salt Lake Herald Republican.
Scientific Farmer.
Sea Power.
Shepherd's Journal.
Smithsonian Institution, Contribution to U. S. National Museum.
Smithsonian Bulletins, U. S. National Museum.
Smithsonian Miscellaneous Collections.
Societa degli Agricolturi Italiani.
Southern Fruit Grower.
Special Crops.
Square Deal Magazine.
Standard and Poultry World.
Successful Farming.
Successful Poultry Journal.
Sugar.
Thresherman's Review.
Tribune-Messenger.
Tuscola County Advertiser.
Up-to-date Farming.
Vertical Farming.
Wallace's Farmer.
Weather Review, U. S. Department Agriculture.
Weekly News Letter, U. S. Department of Agriculture.
West Indian Bulletin.
White Breeders' Companion.
Williamston Enterprise.
Wilson Bulletin.
Yale Review.

The publications of the U. S. Department of Agriculture, and the bulletins of the various state experiment stations, together with the card indexes which cover them, are received and filed in the library. We also receive and file the catalogues from the leading educational institutions of the country. These are received in exchange for our own catalogues.

The number of books loaned during the year for home use was 9,075. The largest number went out during the month of February, and the smallest number in September. The numbers loaned during those months being 1,158 and 243 respectively.

We desire to acknowledge our indebtedness to the librarians of the John Crear library, the Library of the University of Michigan, the Johns Hopkins Library, the Library of the U. S. Surgeon General and the Library of the U. S. Department of Agriculture, for books and periodicals which they have kindly loaned to us.

We have only words of commendation for our assistants, both of whom have been faithful in the discharge of their duties, and both of whom are leaving at the close of the year. Miss Trebilcock, who came to us for one year only, has accepted a position as teacher of domestic science, and Miss Carpenter has decided to give up library work, and has accepted a position in the public schools of her home city. Miss Palm, who has been away on leave of absence during the year, will return to us, and her many friends will be glad to welcome her. Mr. Halsted, our student assistant, has proved most efficient, and will remain with us next year.

Additional stackroom has been provided by means of excavating beneath the Library Building, and the placing of book shelves and electric lights in the room thus afforded. This extra room has enabled us to bring into the Library Building all library matter that had for so many years been stored in various places on the campus, and we take occasion to thank you, Mr. President, and the members of the State Board, for the convenience afforded by having everything under one roof.

With the burning of the Engineering Hall the college lost 167 volumes that had been catalogued for the various departments housed in that building. We have no record of the uncatalogued books.

During the winter term, and the early part of the spring term, the library doors were opened at 7:30 a. m., instead of 8 o'clock for the accommodation of non-resident students who might arrive upon the grounds too early for the first class period. With this exception, the library hours have remained unchanged.

To the library of the Experiment Station there have been added 122 volumes, of which 19 were purchased, 13 were gifts, and 90 came by binding. This library contains 5,077 bound volumes. The College library numbers 37,123 volumes. Total in both libraries, 42,200 volumes. This number includes all department books so far as they have been catalogued.

Respectfully submitted,
LINDA E. LANDON,
Librarian.

East Lansing, Michigan, June 30, 1916.

REPORT OF THE REGISTRAR.

President F. S. Kedzie, Michigan Agricultural College:

Dear Sir—I herewith submit my report for the past year.

The total enrollment in the different divisions is as follows:

REGULAR FOUR YEAR COURSES.

Agriculture and Forestry	874	
Engineering	408	
Home Economics	368	
Veterinary Medicine	67	
Total		1,717

SHORT COURSES.

Two Year Course in Agriculture	170	
Eight Weeks Course in Agriculture and Home Economics	217	
Total		387
Total in all courses		2,104
Names repeated		111
Net Total		1,993

ENROLLMENT BY TERMS.

Course.	Summer.	Fall.	Winter.	Spring.
Agriculture and Forestry	93	744	709	665
Engineering	35	378	334	313
Home Economics	38	317	307	288
Veterinary Medicine	9	44	47	45
Graduate		16	14	15
Totals	175	1,499	1,411	1,326

ENROLLMENT BY CLASSES.

	Agriculture.	Engineering.	Home Economics.	Forestry.	Veterinary.	Totals.
Graduates	20		2			22
Seniors	113	71	64	11	6	265
Juniors	140	83	60	12	12	307
Sophomores	210	88	71	12	18	399
Freshmen	248	131	120		22	521
Special Students	15		13			28
Summer S'n, 1915	81	35	38	12	9	175

WITHDRAWALS.

	Fall.	Winter.	Spring.
Voluntary	139	91	
Scholarship	18	7	8
Discipline			

GEOGRAPHICAL DISTRIBUTION OF STUDENTS.

MICHIGAN.

Counties:	
Alcona	1
Allegan	12
Alpena	10
Antrim	5
Arenac	3
Baraga	1
Barry	16
Bay	22
Benzie	6
Berrien	34
Branch	20
Calhoun	30
Cass	8
Charlevoix	3
Cheboygan	1
Chippewa	4
Clare	1
Clinton	14
Crawford	2
Delta	11
Dickinson	14
Eaton	19
Emmet	12
Genesee	33
Gladwin	3
Gogebic	4
Grand Traverse	20
Gratiot	12
Hillsdale	25
Houghton	19
Huron	8
Ingham	231
Ionia	12
Iosco	7
Iron	4
Isabella	10
Jackson	32
Kalamazoo	25
Kalkaska	4
Kent	66
Lake	1
Lapeer	8
Leelanau	4
Lenawee	25
Livingston	9
Luce	1
Mackinac	1
Macomb	9
Manistee	5
Marquette	19
Mason	14
Mecosta	5
Menominee	4
Midland	7
Missaukee	3
Monroe	5
Montcalm	8
Muskegon	19
Newaygo	12
Oakland	31
Oceana	18
Ogemaw	1
Osceola	10
Otsego	1
Ottawa	21
Roscommon	1
Saginaw	26
Sanilac	13
Schoolcraft	8
Shiawassee	15
St. Clair	25
St. Joseph	18
Tuscola	13
Van Buren	26
Washtenaw	15
Wayne	94
Wexford	7

OTHER STATES AND COUNTRIES.

Arkansas	1
Bulgaria	1
California	4
China	3
Connecticut	10
Colorado	1
Greece	1
Illinois	25
Indiana	23
Kansas	3
Kentucky	2
Maine	1
Massachusetts	12
Minnesota	3
Missouri	3
New Hampshire	4
New Jersey	5
New Mexico	1
New York	63
North Carolina	1
North Dakota	1
Norway	1
Ohio	54
Oklahoma	2
Pennsylvania	26
Scotland	1
South Carolina	1
South Dakota	1
Tennessee	1
Texas	1
Turkey	2
Vermont	7
Virginia	1
Washington	1
West Virginia	1
Wisconsin	3
Wyoming	2
Dist. of Columbia	4

DEGREES GRANTED JUNE 14, 1916.

BACHELOR OF SCIENCE.

a, Agriculture; e, Engineering; h, Home Economics; f, Forestry.

Alderman, Abe Leroy, e.
Anderson, Harriett Louisa, h.
Atchison, William Joy, a.
Atzenhoffer, Arthur Herman, e.
Avery, James Walker, a.
Awotin, Arnold, a.
Barlow, Glenn Alvin, e.
Barron, Allen Willard, e.
Bates, Sadie Isabelle, h.
Beach, Elinor Frances, h.
Beatty, Elmer Earl, e.
Beatty, Howard Elsworth, e.
Beden, Wallace Seth, a.
Berry, James Alexander, a.
Betts, William Henry, e.
Bigelow, Royal Gilbert, e.
Bloemendal, George William, e.
Boatman, Serene August, f.
Bogan, George Richard, a.
Bos, Gerald, a.
Bottomley, Myrl Elijah, a.
Brandell, Bernard Henry Andrew, a.
Brown, Waldo Berkey, e.
Brownell, Stanley J., a.
Buell, Warren Monroe, e.
Bunt, Floyd, e.
Cade, Mary Blanche, h.
Caray, Glenn Waldo, a.
Caray, Nina Lucille, h.
Carlson, Floyd Alfred, a.
Casterton, Ethel Marion, h.
Childs, Francis Marion, a.
Clark, Harold Allison, a.
Coburn, Laurance Fred, e.
Cole, Laura M., h.
Coleman, Rose, h.
Cooper, Herbert Goddard, a.
Coppens, Pauline Mary, h.
Cowles, Howard Elwyn, a.
Crisp, Harry James, a.
Croninger, Lydia Mae, h.
Cushman, Elmer Edward, a.
Daprato, Neno Joseph, a.
Davis, Carol Marie, h.
DeYoung, Martin James, e.
Dimmick, Thomas Burdon, e.
Dunn, Percy John, a.
Edison, Helen Jean, h.
Eichelberger, Maurice Barkley, e.
Eisenlohr, Amanda Isabel, h.
Eriksen, Rudolph, a.
Felt, Lutie Pauline, h.
Ferle, Allan Weldon, a.
Fisher, Lawrence Drake, e.
Freeman, Milton Rush, a.
Friedrich, Oliver Henry, e.
Frost, George Barton, a.
Fuller, Henry Harrison, a.
Fuller, Merrill Sylvester, a.
Godfrey, Alfred John, a.
Godkin, James, a.
Gork, Lewis Henry, a.
Gorton, Walter Thomas, e.
Greve, Lyman Tilden, f.
Gruner, Vera, h.
Hacker, Fern Geraldine, h.
Hacker, Forest Glen, a.
Haddon, Margaret Jane, h.
Hagedorn, Frederick Arthur, a.
Halsted, Bessie Althina, h.
Hamlin, Edgar Gale, f.
Handy, Kittie Marie, h.
Hatch, Helen Fern, h.
Heitsch, Helen, h.
Hendricks, Lauretta M., h.
Henning, George Leslie, a.
Hess, Samuel Otto, e.
Hinyan, Reeva Irene, h.
Hobbs, Glenn Irvin, a.
Hogue, Rozetta Julia, h.
Holihan, Glenn Gallinger, e.
Horan, Harold John, e.
Hunzicker, Alfred Herman, a.
Hurd, Ruth E., h.
Ide, Zelma Celia, h.
Jackson, Roland Burnard, e.
Jackson, Truman Lewis, e.
Jensen, Michael Byron, e.
Jessop, Henry Alexander, a.
Johnson, Charles Hans, f.
Johnson, Elsie Marie, h.
Johnson, James Merrill, e.
Johnson, Ralph John, f.
Jones, Don Fred, e.
Jones, Laverne, h.
Keating, Esther Ann, h.
Kelley, William Cornelius, a.
King, Karl Burnett, a.
Kinney, John Miller, a.
Kivela, Emil Wilfred, e.
Knickerbocker, Walter George, e.
Knudson, Robert O., e.
Kuenzli, Alice May, h.
LaFever, Albert Martin, a.
Lahym, Gladys Lucile, h.
Lankey, Francis Irving, e.
Larson, Emil Waldemar, e.
Lautner, Robert Wenzel, a.
Layer, John Uriah, e.
Lewis, Dorothy, h.
Lewis, Herdis Leo, a.
Linton, Robert Spencer, a.
Loesel, Clarence Michael, a.
Lux, Gustave Joseph, e.
McCrary, Colond Marvin, e.
MacDonald, Katherine, h.
McDonel, Karl Hanchett, a.
McFarlane, Walter Daniel, e.
McKinley, Grace Porter, h.
Maas, John Baptiste, f.
Makemson, Walter Kenneth, a.
Mans, Louise S., h.
March, Norris Elmer, e.
Martin, Charlotte Grace, h.
Martin, Edward Wheeler, a.
Matteson, Roy Emerson, e.
Maze, Jacob Moses Handel, a.
Meisel, Frieda Mary, h.
Melican, Martin Bernard, a.
Menerey, Earl James, e.
Miller, Clayton Carrick, a.
Miller, Hiram Hewitt, a.
Miller, William Blake, a.
Milroy, Claude Baird, e.
Moll, Bernard, e.
Moore, John Morris, e.
More, Ellsworth Burnette, a.
Morrison, Victor Nelson, a.
Morse, James Lyman, e.
Morton, Henry Earl, e.
Murphy, William, a.
Nelson, Raymond, a.
Nicholls, Clarence Alfred, f.
Nobles, Charles George, a.
Normington, Olive Louise, h.
Oakes, Henry George, e.
O'Callaghan, John Washington, a.
Olin, Mae Belle, h.
Olsen, Arnold Lauritz, a.
Olson, Olaf Arthur, f.
Osgood, Douglas Harry, a.
Oviatt, Clarence Roy, a.

Pardee, Lynn J., a.
Patch, Gifford, Jr., a.
Peabody, Ford, a.
Pellett, George Watrous, a.
Peterson, Ralph Wesley, a.
Petrie, Helen Winifred, h.
Phelps, Narcissa, h.
Pierce, Sylvester Samuel, a.
Piper, George, a.
Postiff, Claude, e.
Pratt, Anna Claribel, h.
Pratt, Helen Columbia, h.
Pressler, Frederick Herman, a.
Pressley, Cecil Perth, a.
Price, Ruth M., h.
Proctor, Merrill Albert, a.
Puhle, Bertha Henrietta, h.
Ralya, Lynn, a.
Raven, Clarinda Ayesha, h.
Rawson, Walter Jones, a.
Reed, Irvine Nixson, e.
Reed, Rhoda Robin, h.
Richards, Charles Newton, a.
Richards, Harry John, e.
Ricker, Fred George, e.
Ritchie, Arthur John, e.
Robb, Elda Iantha, h.
Robinette, Allan Barzilla, a.
Rood, Paul Joseph, a.
Russell, Nita Octavia, h.
Rutherford, Anna, h.
Sears, Lucius Daniel, a.
Secrist, Gerald Allison, a.
Semenow, Saul David, a.
Shearer, Marshall H., a.
Shields, Oscar Simon, a.
Smallegan, Alice Elizabeth, h.
Smith, Carl Albert, a.
Smith, Everett Grant, a.
Smith, Gideon Edward, a.
Smith, Justin Porter, e.
Spencer, Earl Henry, e.
Stafford, James McNutt, a.
Stanley, Leo Roswell, a.
Steele, Eugene Robert, e.
Stinson, Harold Cecil, a.
Stoll, Florence Amelia, h.
Swank, Kinley Roy, a.
Swift, Leah Esca, h.
Taft, Ethel, h.
Taggart, Van Cleve, a.
Thomas, Walter Phelps, f.
Thomason, Lillie Ethel, h.
Thompson, Chester Earl, e.
Thompson, Frank Burton, a.
Thompson, Fred Avery, f.
Torezken, Abraham, a.
Tower, Paul Vivian, f.
Trezise, Frederick William, e.
Turner, Bessie Burdick, h.
Ulbright, Ralph Allyn, e.
Utley, Uhl, e.
Vaileau, Russell Frank, a.
Van Aken, Hugh Marcus, a.
Van Buren, Jacob, e.
Vedder, Katharine Helen, h.
Wagner, Ruth Evangeline, h.
Waltz, Albert Lewis, a.
Warmington, Thomas Jeffery, e.
Warren, Gilbert Ray, a.
Waters, Carl Bliss, a.
Weaver, Lloyd Leander, e.
Webber, Henry James, e.
Wells, Louis Silas, a.
Wheeting, Lawrence Clifford, a.
White, Ralph Dexter, e.
Wilder, Louella Maud, h.
Williams, Loren, a.
Williams, Ruth Marion, h.
Willoughby, George Alonzo, e.
Wilson, Luther Earl, a.
Winslow, Arthur Banister, a.
Winston, Clarence Noble, e.
Wright, Arthur Wilbur, e.
Wright, Helen Abigail, h.
Wyant, Royce Willard, a.
Yates, Everett Claudius, a.
Zieske, Emma Ottille, h.

DOCTOR OF VETERINARY MEDICINE.

Bates, Frank Reed
Couchois, Clifford John
Hough, Earle Mansfield
Massie, Wilfred Bernard
Runnells, Russell Alger
Sales, Edward Karns

MASTER OF SCIENCE.

Fu, Pow Kwang
Gruzit, Oswald Martin
Harrington, Oscar Edwin
Harvey, Earl Munn
Krakover, Leo Julius
Ockerblad, Frederick Otto
Wolkoff, Michael Ivanovitch

MECHANICAL ENGINEER.

Fuller, George Brinkerhoff
Hartman, William Henry
Valentine, Floyd Herbert

CIVIL ENGINEER.

Hitchcock, Warren Wayland
Neilson, Wilhelm

MASTER OF FORESTRY.

McKibbin, Clifford Worden
Wales, Henry Basil

HONORARY.

Charles Christian Georgeson, D. Sc.

In addition to the above, the following degrees were granted at the close of the summer session, 1915:

BACHELOR OF SCIENCE.

Hagy, Russell Jacob, a.
Plumstead, Charles Edward, a.
Vaughan, Florence S., a.

MASTER OF SCIENCE.

Beach, Walter Spurgeon	Peiser, Kurt

SUMMARY OF DEGREES GRANTED DURING THE YEAR 1915-16.

Bachelor of Science:		
Agricultural Course	104	
Engineering Course	66	
Forestry Course	11	
Home Economics Course	62	
		243
Doctor of Veterinary Medicine		6
Master of Science		9
Professional Degrees		7
Honorary Degree		1
Total		266

STATISTICS OF ENTERING CLASS.

Number enrolled.

Agricultural Course	265
Engineering Course	130
Home Economics Course	132
Veterinary Medicine Course	13
Total	540

Preparation and Admission.

Graduates of Accredited High Schools	426
High School credits and Examinations	16
Credits from other Colleges	98
Total	540

CHURCH AFFILIATIONS.

	Members.	Preference.	Total.
Adventist	1	....	1
Baptist	26	11	37
Catholic	16	3	19
Christian	7	1	8
Christian Reformed	....	1	1
Christian Science	1	4	5
Church of Christ	3	....	3
Congregational	37	25	62
Disciple	1	1	2
Dutch Reformed	1	....	1
Episcopal	20	11	31
Evangelical	4	....	4
Friends	....	1	1
Jewish	....	4	4
Lutheran	14	4	18
Menonite	1	....	1
Methodist Episcopal	87	79	166
Methodist Protestant	3	....	3
Presbyterian	55	34	89
Reformed Presbyterian	4	2	6
Swedenborgian	....	1	1
Swedish	....	1	1
Unitarian	1	1	2
United Brethren	1	....	1
United Presbyterian	1	....	1
Universalist	1	3	4

The remainder of the class expressed no preference.

FATHER'S OCCUPATION.

	Agricultural.	Engineering.	Home Economics.	Veterinary.	Total.
Agent	4		1		5
Artist	1				1
Baker	2	1			3
Banker	1	1			2
Blacksmith	1	1	2		4
Bookkeeper	1	1	1		3
Carpenter	3	5	1		9
Contractor	7	1	2		10
Clerk	4	2	4		10
Dentist	2	2	1	1	6
Electrician		2			2
Engineer	5	8	3	1	17
Farmer	106	31	32	4	173
Foreman	1	5			6
Horticulturist	1		1		2
Insurance	3	2	3		8
Laborer, Common	7	1			8
Laborer, Skilled	13	4			17
Lawyer	7	1	2		10
Lumberman	4	3	1		8
Machinist	1		1		2
Mail Carrier	2	1	2		5
Manager	4	3	2		9
Manufacturer	8	5	5		18
Mechanic		3	1		4
Merchant	15	11	15	1	42
Miner	1	1			2
Minister	4	2	3		9
Nurseryman	3				3
Photographer		1		1	2
Physician	2	4	9		15
Postmaster	1	2			3
Plumber	1	1			2
Printer		1	1		2
Retired	4	5	5	1	15
Real Estate Dealer	4	2	1		7
Salesman	2	3	3		8
Superintendent	2	2	1	1	6
Teacher	4		3		7
Veterinarian			2		2
Miscellaneous	9	4	7		20
Not stated	26	8	19	3	56

This year data was compiled and a graph prepared, with the assistance of the Department of Mathematics, showing the comparative class standings of the different literary societies at the College. We have every reason to believe that the effect of this has been sufficiently good to warrant a continuance of the plan from year to year.

A new plan of registration and classification was also put into effect this year. While it is too soon to make a careful judgment of the scheme, the saving of time for both student and instructor, as well as other features of the plan, would make it advisable to adopt it another year.

The routine work of the office such as recording of grades, publishing the annual Catalog and Student Directory, assigning dormitory rooms and the making of schedules, has been carried on as usual with the assistance of Miss Anna Ferle, Assistant Registrar, and student help at various times.

Respectfully submitted,
ELIDA YAKELEY,
Registrar.

East Lansing, Michigan, June 30, 1916.

REPORT OF THE DIRECTOR OF SUMMER SESSION.

President F. S. Kedzie:

Dear Sir—I herewith submit a report of the work of the Summer Session for 1916.

The session opened June 19 and closed July 28. The date for opening this session should be carefully considered, since several teachers in attendance this year were compelled to enter late because their schools did not close until opening week of our session.

The following statistics will convey information of importance and interest:

Total number of students classified	239
Number of men	156
Number of women	83
Number of regular students	128
Number of County Normal Teachers	5
Number of rural teachers	15
Number of new students (first enrollment)	62
Number of graduates of M. A. C. enrolled	28
Number of graduates of other institutions	36
Number of candidates for advanced degrees enrolled	17
Number of delinquents (partly or wholly)	38

DISTRIBUTION OF STUDENTS.

Animal Husbandry	14
Poultry Husbandry	..
Bacteriology	48
Botany	15
Chemistry	62
Dairy Husbandry	11
Drawing	6
English	25
Entomology	4
Farm Crops	9
Forestry	11
History and Economics	67
Home Economics:	
Domestic Art	26
Domestic Science	16
Horticulture	9
Mathematics	41
Manual Training	7
Pedagogy	13
Physics	22
Physiology	8
Veterinary Medicine	7
Special courses in Agriculture for rural teachers	20

The attendance has been sixty-four larger than last year. The enrollments have been distributed through a large number of departments with a considerable degree of uniformity.

I would direct your attention to several features of the session deserving of special comment in this connection.

The record of attendance shows that twenty-eight graduates of M. A. C. have been enrolled in this session; also that, thirty-six graduates of other institutions, including the University of Michigan, Olivet, Hillsdale, have been in attendance. Furthermore, that seventeen students have been in residence as candidates for advanced degrees. More students of this type have availed themselves of the Summer Session this year than in previous years. A large percentage of these persons can be with us only in the summer.

This year the College offered for the first time, special courses for teachers in the rural schools, and for county normal teachers. These courses included the different lines of agriculture, including farm crops, soils, animal husbandry, dairy husbandry, poultry husbandry and horticulture, also home economics, rural pedagogy, and a special course in English. The State law requires the teaching of agriculture in the rural schools. Obviously the teachers for these schools have had little opportunity to be trained for this purpose. Aside from the very elementary courses given in the State Normals, and the work in agriculture in high schools through the State, there is no opportunity for these teachers to get instruction. It is natural that the public should look to the College to contribute to the stupendous problem of preparing the 7,500 rural teachers to perform this duty of teaching agriculture more intelligently. The College can not be expected to give class room instruction to this army of teachers, but it may render invaluable service by training those who are to teach the rank and file. This would include the teachers of agriculture in the forty-five county normals; also, by extending the teaching of agriculture in the secondary schools. At the same time, it should provide for instructing such numbers of rural teachers as can be brought to the campus during the Summer Session. Another function for the College in this connection and one of fundamental importance, is that of shaping the subject matter to be taught under the name of agriculture. At present the content of the term agriculture is undetermined. Much has been written in the way of text-books, but the subject matter is not standardized. The College can perform a large function in helping to shape up this content and to put into the hands of the teacher serviceable literature. At the suggestion and the direction of yourself and Dean Shaw, this plan is already under way.

Much of the foregoing may be said about home economics. Although not required as a subject in the rural school as yet, there is demand for instruction in it by the teachers. Dean White and her associates have offered such work for rural teachers for the first time this summer, with highly satisfactory results.

Courses in rural pedagogy and English, designed to assist rural teachers, were given for the first time. The former dealt with the matter of teaching and organization of the rural school, while the latter sought to give instruction in ways of furnishing recreation and entertainment for rural communities. These courses proved to be very attractive and acceptable to a goodly number of the teachers in attendance.

For the first time, the Summer Session offered work in manual training and drawing. A small group enrolled in these subjects, but the members were very appreciative of the value of the instruction given to them as prospective teachers. No doubt more would have enrolled in this had our announcement in the bulletin been more specific as to the nature of the work and the amount of credit to be received. I believe courses in these lines can be made very attractive and helpful to teachers if they are adapted to the needs of such students.

Widespread interest prevails in our State at present in the economic problems pertaining to agriculture, such as cooperation, marketing and farm accounting. In order that the best thought in these lines might be presented, the Department of Economics arranged to have specialists present a series of lectures during the session. Accordingly Dr. A. L. Cance of Amherst, Massachusetts, lectured for two weeks on the topic of Cooperation; Dr. E. D. Jones, Ann Arbor, two weeks on Marketing; Dean J. A. Bexell, Corvallis, Oregon, and Mr. R. V. Gunn of Madison, Wisconsin, on Farm Accounting. A class of thirty-seven enrolled for these lectures. More detailed account of this work will appear in Dr. Hedrick's department report.

Finally, I would direct attention to the conferences. Dean White has held two conferences; one for teachers and for women of the State interested in home economics, and another for demonstrations in household affairs. The satisfactory results from these conferences amply justify their existence. I refer the reader to Dean White's report for further comment.

Mr. E. C. Lindermann, State Leader in Charge of Boys' and Girls' Club Work for the State held a conference of persons interested in club work. Sixty-four persons were in attendance from various parts of the State. The object of the session was to give specific instruction to individuals who desire to become leaders of local clubs. No activity of the summer has equalled this gathering in enthusiasm and genuine interest. This short course of instruction will be of incalculable value to the interests of the club work of the State. The College may well afford to emphasize this project in the coming Summer Sessions.

There remains for comment, the Rural Leaders Conference, similar to that of last year, and designed to render assistance to ministers upon rural charges and any others interested. Forty persons enrolled for this, thirty-three of whom were pastors in rural charges. The problem of assisting the rural pastor to adjust himself to the needs of his parish is one of tremendous import and of immeasureable difficulty, the importance of which is as yet very slightly appreciated. The instruction given in an agricultural college, and the environment of such an institution ought to contribute to this end. Through the aid of our faculty, supplemented by the addresses of Dr. Warren H. Wilson of New York City, Dean Shailer Mathews of the University of Chicago, and Prof. T. J. Meek of James Millikin University, Decatur, Ill., a splendid program was presented. The most potent tribute to this effort is the fact that representatives of four denominations have asked the College to continue this activity, and have effected an organization among themselves to relieve the College of responsibility as well as to secure larger attendance of their members.

The problems of the conferences are among the most taxing upon the administration of the session. If it were not for the far reaching value of such efforts, the plans would be quickly abandoned, but when thoughtful men and women in our own State and other states accept these as worth while efforts, it is difficult to turn a deaf ear to the appeals for service of this kind.

The Summer Session is indebted to members of the faculty for interesting and instructive addresses upon the Extension work of the College. A similar indebtedness is due to our teachers for efforts in a social way, including the presentation of Peer Gynt on the opening Friday evening, the picnic, the lawn fete and the social evenings. To all who participated to make these features so attractive, we would convey our appreciation.

In general the Summer School program has been arranged along lines peculiar to this institution, and in so far as possible, not a duplication of similar sessions of other institutions. These features should be stressed more and more. Experience, as yet limited as compared with summer sessions of other institutions of the State, points to the certainty of response along these lines when the character of our courses becomes widely known.

In conclusion, I want to testify to the earnest work done by our student body of the summer, and the splendid cooperation of the instructional force who have devoted themselves with unstinted measure to their individual lines of work in the interests of the student body and the success of the Summer Session.

All of which is respectfully submitted,

E. H. RYDER,
Director Summer Session.

East Lansing, Mich., June 30, 1916.

REPORT OF STATE INSPECTOR OF NURSERIES AND ORCHARDS.

To the State Board of Agriculture:

Gentlemen—During the year now closing, the department has responded to a considerable increase in the number of calls for assistance. There are not only more nurseries requiring inspection, especially those growing small fruit plants and ornamentals, but local inspectors have also asked for more than the usual amount of assistance.

THE MICHIGAN NURSERIES.

Especial attention is given to the nurseries in order that the stock grown may be free from dangerous insects and diseases, and we are glad to report that their condition has never been better. Not only do the nurserymen more fully appreciate the danger that may come to their business but they are more familiar with the insects and diseases and the remedies that should be used for them, as well as more expert in their application. Greater precaution is also exercised about starting nurseries in sections known to be infested with dangerous insects and diseases.

At the leading nursery center of the State,—Monroe,—arrangements were made by this department with the proprietors of the nurseries by which one of the deputy inspectors should spend most of the summer there on the watch for outbreaks of any kind that might occur, and advising and aiding in their control. He was able to report at the end of the season that he had not found San Jose scale in any of the nurseries and, with the exception of a small amount of crown-gall and woolly aphis, the trees were apparently free from dangerous insects and diseases. The trees infested with the above insects were destroyed when dug.

The other nurseries in the State were in excellent condition.

WORK WITH LOCAL INSPECTORS.

Fruit growers are each year convinced that it is only by organized effort that it is possible to control the more dangerous orchard diseases and insects, such as peach yellows and the San Jose scale, and we have been able to secure the appointment of local orchard inspectors in a large number of townships and villages.

While many of the appointees are familiar with the insects and diseases which come under their observation, as well as with the duties of their office, such is not always the case, and considerable time has been spent with local inspectors where we have felt it would be beneficial.

We have also been called in on several occasions where there was a difference of opinion between the owners and the local inspectors.

Many requests also come to this office for assistance by orchardists who believe some serious trouble threatens their trees. In many cases we are able to ascertain the nature and prescribe the remedy by having specimens forwarded, while in others, personal visits are necessary.

INSPECTION OF IMPORTED NURSERY STOCK.

Although it might be expected, owing to the war in Europe, that the amount of imported stock would be considerably less than formerly, such has not been the case, the principal difference noticeable being that owing to delays in transportation, chiefly after it has left New York, much of it has reached the Michigan consignees in a damaged condition. The stock received has been free from dangerous insects and diseases, indicating that in the nursery districts of France as well as Holland, from which countries most of the stock has come, more than usual attention is being paid to the nurseries, and the inspection work is carefully done.

SHIPMENTS FROM GYPSY MOTH AREA IN THE UNITED STATES.

During the last two years reports have been received at this office of all shipments not only of nursery stock but of lumber, granite and other articles from sections in New England in which the gypsy and brown-tail moths are found. These go direct to planters in all parts of the State and it has not been possible to have many of them officially inspected, but in all cases we have notified the consignees of the danger of bringing in injurious insects and have asked them to carefully examine the trees and plants.

From the fact that all of these shipments have previously been inspected in the nursery by state and Federal officials, we felt this would make the shipments comparatively safe. To inspect all of the shipments would double the present cost of nursery inspection.

Early in June the Federal authorities requested the inspection of several shipments of cranberry vines from Massachusetts which were shipped before the quarantine was established, and which had not been inspected. Although the egg masses of the gypsy moth are frequently found upon cranberry vines in Massachusetts, we were unable to find any indication that the insect has been brought to Michigan.

WHITE PINE BLISTER RUST.

For several years considerable harm has been done to the white pine in New England, New York, New Jersey and Pennsylvania by the blister rust. It has also been found in Ohio and Indiana, and this spring white pines in several places in Wisconsin and Minnesota have been found to be infected.

Owing to the fact that extensive plantings of white pine have been made in Roscommon and several neighboring counties by the Public Domain Commission, by Messrs. Ward and Mershon in Crawford county, and by the Cleveland Cliffs Company in Marquette county, as well as by hundreds of small planters over the State, it is important that steps be taken to prevent the introduction of the disease upon nursery stock. Even before the quarantine against shipments of white pines from Europe was put into effect very few were imported, and comparatively few, if any, shipments from the infested areas of other states have come into Michigan, and most of these have been used for landscape purposes upon private grounds near Detroit and other large cities.

It is very difficult to detect this disease, as it may remain dormant in the tissues of the tree for several years before it manifests itself externally. Like many of the other rusts, the white pine blister rust attacks the five-needle pines in one form, or stage, of its development and then passes to the currants and gooseberries, both wild and cultivated, upon which it remains for the balance of the year, passing through its other two stages, after which it again attacks the pines.

There is, therefore, not only danger that the disease may be brought in upon pine trees but it may be imported upon currants and gooseberry plants and from them spread to pines growing in the vicinity. The danger is somewhat lessened by the fact that the currant leaves only are attacked and for the most part these are stripped before the plants are dug.

During the month of June, Professor Roy G. Pierce, Forest Pathologist of the Bureau of Plant Industry, U. S. Department of Agriculture, came to Michigan and the principal forest plantations, as well as several of the private grounds upon which white pines have been planted, were inspected without finding any traces of the disease, and we have no reason to think it has secured a foothold in Michigan.

From the nature of the disease the most careful inspection will be of little value and it is important that unless a national quarantine against interstate shipments from infected regions is provided, our state law be so amended as to make it possible to put on a quarantine, or embargo, against the shipping of white pine trees into Michigan from states known to be infected.

THE CONDITION OF MICHIGAN ORCHARDS.

While it is true that in many sections in Southern Michigan the farm orchards have been partially or quite destroyed by the San Jose scale, it is really the best thing that could happen to them as most of them are old and have never received much attention. Such trees produce little or no fruit and what they furnish is of no practical value. When the law is enforced and the owners are compelled to spray the trees, even though they think they do it thoroughly, the work is generally so imperfectly performed that it has little effect in controlling the scale, and it merely results in prolonging the life of the trees and distributing the scale.

The spraying of orchards for this and other scale insects has gradually increased until in many sections, and especially in the so-called "fruit regions," it is the exception that an orchard is left unsprayed. Each year the importance of thoroughness and regularity in making the applications is better understood and fewer mistakes are made in the materials used.

Another hopeful as well as helpful point in the control of this insect is that various native parasites are working upon it and in some sections trees which formerly were badly infested are now practically free from the scale even though they have not been sprayed.

Peach yellows, little peach and black knot have been less troublesome than formerly, due very largely to the owners of infected orchards giving more attention to the prompt removal of infected trees.

For a number of years the apple trees, as well as wild cherry and other trees in the northern part of the State have been covered with the "tents" of apple tree tent caterpillars, but, although they were still plentiful in some sections, over a large area where they did much harm in 1914, it was difficult to find them in 1915. This was due to parasites which attacked them as larvae and to some extent in the egg and pupal stages.

LIST OF NURSERYMEN AND DEALERS LICENSED TO SELL NURSERY STOCK IN MICHIGAN.

The following nurserymen and dealers are allowed to do business in this State, having taken out a license as is required by the law. Only such nurserymen living in another state as have taken out a license are authorized to sell stock in Michigan through agents or canvassers, but they may without a license carry on what is known as a catalogue or mail order business.

NURSERIES LICENSED IN MICHIGAN FOR 1915-16.

Allen Bros., Paw Paw.
Allis, E. W., Adrian.
Augustine & Co., Normal, Ill.
Babcock & Son, Charlevoix.

Bagley, W. D., Old Mission.
Baldwin, O. A. D., Bridgman.
Bashford, C. L., Mason.
Bennken, J. H., Jerome.
Bigelow, J. N., Bangor.
Bliss, A. W., Harbor Springs.
Boehringer Bros., Bay City.
Bohl, William, Buchanan.
Bridgman Nursery Co., Geo. W., Benton Harbor.
Brooks & Co., J. C., Detroit.
Brown, Douglas M., Grand Rapids.
Browne, Geo. E., Greenfield.
Burgess Seed and Plant Co., Galesburg.
Burrass, W. V., Lowell.
Celery City Nursery Co., Kalamazoo.
Cole, Levant, Battle Creek.
Collins, Ward E., Fennville.
Coryell Nursery, The, Birmingham.
Cukerski, Wencil C., Grand Rapids.
Cutler & Downing Co., Benton Harbor.
Daly, Thomas W., Watervliet.
Dalzell, Bernard F., Muir.
Dean, Geo. N., Shelbyville.
Detroit Shade Tree Co., Detroit.
Dressel, G. L., Frankfort.
Dunham, Enos W., Baroda.
Elliott, Hanson B., Trenary.
Emlong & Son, Henry, Stevensville.
Ferrand & Son, E., Detroit.
Fetters, Theodore J., Harbor Springs.
Flansburgh & Son, C. N., Jackson.
Fisher, Guyon, Fennville.
Frey, Mrs. Anna, Sand Lake.
Genesee County Nurseries, Flint.
Gill, Mrs. B. M., Ypsilanti.
Glenwood Nurseries, Holland.
Gobleville Nurseries, Gobleville.
Godfrey, John, Benton Harbor.
Gohs, Frank, Mayville.
Greening Nursery Co., Monroe.
Gustin, C. F.. Adrian.
Hamilton & Sons, A., Bangor.
Havekost, G. H., Monroe.
Hawley, Geo. A., Hart.
Hawley, H. E., South Haven.
Helmer Farm Nursery, Battle Creek.
Hemingway, Geo. R., Oak Park, Ill.
Hibbler, E. B., Detroit.
Hurlbut & Cross, Bangor.
Ilgenfritz Sons' Co., I. E. Monroe.
Insulinde Nurseries, Kalamazoo.
Irvine, John, Bay City.
Isbell & Co., S. M., Jackson.
Jackson & Thurston, Kalamazoo.
Jeffrey, Sr., James, Kalamazoo.
Kalamazoo Nurseries, Kalamazoo.
Kalle Bros., South Haven.
Katzenberger, Val., Saginaw.
Keith Brothers' Nursery Co., Sawyer.
Kellogg Co., R. M., Three Rivers.
Knight & Son, David, Sawyer.
Krieger, William, Lansing.
Lanphear Brothers, Hartford.
Lohrman Seed Co., Detroit.
Lumley, L. B., Mayville.
McCormick Nursery Co., Monroe.
Marvin, O. F., Holton.
Mayer, Jr., Michael, Merrill.
Merrill, W. F., South Haven.
Mershon, W. B., Saginaw.
Michigan Nursery Co., Monroe.
Miller, Abner, Bravo.
Miller, J. W., Fremont.
Munson, Wm. K., Grand Rapids.
Mutual Nurseries, Monroe.
Myers, P. J., Bridgman.
Nelson, Chas. A., Northport.
Nelson & Son, J. A., Paw Paw.
Newell, Reuben, Highland Park.
Oakland Gardens Nursery, Walled Lake.
Olds, W. W., Benton Harbor.
Orchard Lake Nurseries, Orchard Lake.
Pier, Frank D., Traverse City.
Pilkinton & Son, Portland.
Pitcher, W. D., Buchanan.
Pontiac Nursery Co., Detroit.

Potter, E. W., Leslie.
Prestage, J. G., Allegan.
Prudential Nursery Co., Kalamazoo.
Putnam, J. L., Lansing.
Rasmussen, R. J., Marlette.
Reeser, Harry C., Niles.
Rice, Greta B., Port Huron.
Rokely, J. N., Bridgman.
Rouse, Fred E., Woodville.
Saier, Harry E., Lansing.
Schenck, Geo. H., Elsie.
Schild, H. J., Ionia.
Seel, J. J., Frankfort.
Shepard, Chas. E., Bangor.
Smith, Henry, Grand Rapids.
Spielman Brothers, Adrian.
Stahelin & Son, F. C., Bridgman.
St. Joseph Nursery, St. Joseph.
Street, E. L., Wheeler.
Sweet, L. H., McGregor.
Tindall, W. F., Boyne City.
Van Aken Brothers, Coldwater.
Ward, Paul L., Hillsdale.
Westmacott, Harry S., Montague.
Weston & Co., A. R., Bridgman.
Whitten, C. E., Bridgman.
Wise, Ralph, Plainwell.
Wolverine Cooperative Nursery Co., The, Paw Paw.
Wolverine-Detroit Nurseries, The, Detroit.

LICENSED DEALERS IN NURSERY STOCK FOR 1915-16.

Alferink, Albert, Holland.
Asman & Dunn, Detroit.
Beattie, Thomas, Detroit.
Bond, I. J. & O. G., Three Rivers.
Boyd, J. B., Traverse City.
Brown & Co., Clara, Jackson.
Crowley-Milner Company, Detroit.
Cross, Eli, Grand Rapids.
Davison Nursery Co., Davison.
Drake & Jackson, Detroit.
Edwards & Chamberlain Hardware Co., Kalamazoo.
Fair Oaks Nursery Co., Traverse City.
Freyling & Mendels, Grand Rapids.
Frissel, Martin, Muskegon.
Gibson & Son, S. B., Detroit.
Grand Rapids Nursery Co., Grand Rapids.
Greenville Floral Co., Greenville.
Grohman, E. A., Saginaw.
Hallman, W. S., Coloma.
Harris Bros., Mt. Pleasant.
Healy, William, Bloomingdale.
Hotchkiss, C. J., Detroit.
Hudson Co., The J. L., Detroit.
Hughes, C. P., Hillsdale.
Jones' Sons & Co., J. R., Kalamazoo.
Kleinhans, David, St. Louis.
Knapp Co., J. W., Lansing.
Knapp, Wm. F., Monroe.
Knoch, Gustav, Detroit.
Kresge Co., S. S., Detroit.
Northwestern Nurseries, Traverse City.
Pearson & Co., D. S., Detroit.
Plowman & Son, G. F., Iron Mountain.
Quandt, Elmer, Dearborn.
Radewald, Otto, Niles.
Rayl Co., The T. B., Detroit.
Reed, W. F., Flint.
Rickel, Samuel N., Glennie.
Shorewood Farms Co., Saugatuck.
Slanker Nursery Co., Benton Harbor.
Smith & Co., E. M., Detroit.
Smith Mercantile Co., Ira M., Grand Rapids.
Star Nursery, The, Big Rapids.
Stover, F. J., Traverse City.
Strittmatter, A., Detroit.
Trankla & Co., Charles, Grand Rapids.
Valley City Nurseries, Grand Rapids.
Van Bochove & Brother, G., Kalamazoo.
Walther Department Store, Bay City.
Wells, R. H., Detroit.
Westgate Nursery, The H. L., Monroe.
Winkworth, R. M., Detroit.
Wood, Alice, Grand Ledge.

LICENSED FOREIGN NURSERIES FOR 1915-16.

Allen Nursery Co., Rochester, N. Y.
Bogue, Nelson, Batavia, N. Y.
Brow Nursery Co., F. W., Rose Hill, N. Y.
Brown Brothers' Co., Rochester, N. Y.
Bryant Brothers, Danville, N. Y.
Bryant & Son, A., Princeton, Ill.
Burr & Co., C. R., Manchester, Conn.
Cartwright, I. D., Toledo, O.
Central New York Nursery Co., Rochester, N. Y.
Charlton Nursery Co., Rochester, N. Y.
Chase, Charles H., Rochester, N. Y.
Chase Brothers, Rochester, N. Y.
Chase Nurseries, Geneva, N. Y.
Clyde Nursery, The, Clyde, O.
Davis Nursery Co., Franklin, Baltimore, Md.
Dreer, Inc., Henry A., Philadelphia, Pa.
Fairview Nurseries, Rochester, N. Y.
First National Nurseries, The, Rochester, N. Y.
Fruit Growers' Nurseries, Newark, N. Y.
Hall Co., Inc., L. W., Rochester, N. Y.
Harman Co., The M. H., Geneva, N. Y.
Harrison & Sons, J. G., Berlin, Md.
Harvard Evergreen Nurseries, Harvard, Ill.
Hawks Nursery Co., The, Rochester, N. Y.
Hooker Brothers, Rochester, N. Y.
Jewell Nursery Co., The, Lake City, Minn.
Knight & Bostwick, Newark, N. Y.
La Pointe Nursery Co., Newark, N. Y.
Moon Co., The W. H., Morrisville, Pa.
Moore & Co., Wm. C., Newark, N. Y.
Morey Nurseries, The J. B., Danville, N. Y.
McKey Nursery Co., Pardeeville, Wis.
Nelson & Sons' Co., Swain, Chicago, Ill.
Pennsylvania Nursery Co., Girard, Pa.
Perry Nursery Co., Rochester, N. Y.
Rice Brothers' Co., Geneva, N. Y.
Stark Bros. Nurseries and Orchards Co., Louisiana, Mo.
Stoner, J. E., Westminster, Md.
Stuart & Co., C. W., Newark, N. Y.
Taylor & Co., H. S., Rochester, N. Y.
Walton, Cary C., Greenfield, Ind.
Weeks' Nursery Co., Inc., C. H., Lyons, N. Y.
Wheelock & Congdon, North Collins, N. Y.
Woolworth & Co., F. W., Buffalo, N. Y.

Respectfully submitted,
L. R. TAFT,
State Inspector of Nurseries and Orchards.
East Lansing, Mich., June 30, 1916.

REPORT OF THE STATE INSPECTOR OF APIARIES.

To the Honorable State Board of Agriculture:

Gentlemen—In compliance with Section 11, Act 200, 1913, I submit the third annual report as State Inspector of Apiaries for the year ending June 30, 1916.

The early frost in August, 1915, stopped the secretion of nectar very suddenly and from that time till the close of the season bees gathered little nectar. This condition encouraged robbing and caused a great increase in disease this year. From inspection trips and also from reports which have come to this office we have located foulbrood, both American and European, in many apiaries where it was previously unknown.

There has been a large number of calls for inspection which we have been unable to respond to, owing to the limited season and the territory to be covered.

Demonstrations were held in the following places:

Apiary of—	Place.	County.
Mr. A. O. Carley	Munith	Jackson.
Mr. Ward Every	Manchester	Washtenaw.
Mr. Floyd Markham	Ypsilanti	Washtenaw.
Mr. E. W. Thayer	Battle Creek	Calhoun.
Mr. C. E. Glover	Kalamazoo	Kalamazoo.
Mr. F. W. Wilde	Wayland	Allegan.
Mr. Jay Cowing	Jenison	Ottawa.
Mr. H. Dorris	Mason	Ingham.
Mrs. Wilbur Frey	Sand Lake	Kent.
Mr. C. W. Klumpp	Lowell	Kent.
Mr. David Running	Filion	Huron.

The following Michigan queen-breeders apiaries have been inspected and certified free from disease:

Mr. Jay Cowing, Jenison.
M. J. H. Haughey, Berrien Springs.
Mr. M. H. Hunt, Redford.
Mr. E. E. Mott, Glenwood.

Inspection report is as follows:

Number of apiaries visited	118
Number of apiaries not free from disease	54
Number of colonies treated	156
Number of colonies destroyed	14
Number of colonies in apiaries visited	3,831
Number of colonies examined	1,430

Expenses were as follows:

Office expenses, including furniture and stationery	$29 62
Traveling and hotel expenses	550 40
Salary	1,000 00

Respectfully submitted,
F. ERIC MILLEN,
State Inspector of Apiaries.

East Lansing, Mich., June 30, 1916.

REPORT OF ANALYSES OF INSECTICIDES AND FUNGICIDES FOR 1916.

ANDREW J. PATTEN AND E. A. DE WINDT.

To the State Board of Agriculture:

Gentlemen—The purpose of the insecticide law (Act 254, Public Acts 1913) is to prevent the sale of misbranded or adulterated materials intended for use in "preventing, destroying, repelling or mitigating" insects or fungi that may infest vegetation or "be present in any environment whatsoever." This applies not only to materials used in spraying fruit trees, vegetables, etc., but to all materials or mixtures intended for combating insect pests of all kinds wherever found.

All lice powders, cattle dips, roach exterminators, smut destroyers, etc., come under the requirements of the law.

The law provides that all such compounds or mixtures must bear the name and address of the manufacturer and also the "correct names and percentage amounts of each and every ingredient of the insecticide or fungicide having insecticidal or fungicidal properties and the total percentage of inert ingredients." The law further provides that an article shall be deemed to be misbranded if the package or label under which it is sold "shall bear any statement, design or device regarding such article or the ingredients or substances contained therein that shall be misleading in any particular."

The full text of the law has been printed and may be obtained by addressing Secretary A. M. Brown, East Lansing, Michigan.

COLLECTION OF SAMPLES.

One hundred and eight samples, comprising a wide range of materials were collected on the open market by a regular inspector sent out for the purpose.

These have been analyzed and the results will be found in the following pages.

LIME-SULFUR SOLUTIONS.

Eight samples of lime-sulfur solution were collected. Three of the samples were found to be slightly below guarantee for total sulfur but the deficiences were small and might be accounted for by experimental error.

Number.	Manufacturer.	Baume.		Total sulfur.		Calcium Poly-sulfide.
		Found.	Guaranteed.	Found.	Guaranteed.	
				%	%	%
212	Carpenter-Udell Chemical Co., Grand Rapids, Mich	32	....	24.72	23	27.35
231	Carpenter-Udell Chemical Co., Grand Rapids, Mich	31	....	24.58	23	26.33
237	Carpenter-Udell Chemical Co., Grand Rapids, Mich	31	....	24.76	23	25.18
272	South Haven Chemical Co., South Haven, Mich	30	32–33	23.82	24	27.70
283	South Haven Chemical Co., South Haven, Mich	30	32–33	23.47	25	27.05
296	Jas. A. Blanchard, New York	31	....	24.37	....	26.67
220	Dow Chemical Co., Midland, Mich	32	33	24.75	25	25.83
243	Dow Chemical Co., Midland, Mich	32	33	26.42	25	28.73

SOLUBLE SULFUR COMPOUND.

Three samples of soluble sulfur compound were analyzed. Attention is called to the fact that the active ingredient in this compound is sodium polysulfide and that the amounts found were below guarantee in every case. This material deteriorates rapidly on exposure to the air and the containers should be tightly closed at all times.

Number.	Manufacturer.	Total sulfur.	Sodium Polysulfide.	
			Found.	Guaranteed.
		%	%	%
240	Niagara Sprayer Co., Middleport, N. Y	57.69	47.29	56.0
247	Niagara Sprayer Co., Middleport, N. Y	58.89	47.58	56.0
262	Niagara Sprayer Co., Middleport, N. Y	57.12	48.80	56.0

ARSENATE OF LEAD.

The insecticide law fixes the standard for arsenate of lead, making it compulsory for all lots offered for sale to contain not less than 12.50% arsenate oxide and not more than 0.75% arsenate oxide in forms soluble in water nor more than 50% water.

Twenty samples of arsenate of lead were collected, twelve of which were in the form of dry powder and eight in the form of paste. Four samples of dry arsenate of lead contained slightly more than the legal limit for water soluble arsenic oxide but the excess was less than 0.10% in every case which may be disregarded. In every case the net weight of the packages was found to be in excess of that claimed. In one case, No. 270, the amount of water found was 0.91% more than the legal standard.

Number.	Manufacturer.	Water.	Arsenic Oxide (As_2O_5).				Lead Oxide.
			Total.		Soluble.		
			Found.	Guaranteed.	Found.	Guaranteed.	
	DRY POWDER.		%	%	%	%	%
242	Corona Chemical Co., Milwaukee, Wis.	....	31.20	30.00	0.44	0.707*	62.95
264	Corona Chemical Co., Milwaukee, Wis.	....	31.15	30.00	0.83	0.707*	64.55
277	Corona Chemical Co., Milwaukee, Wis.	....	30.10	30.00	0.69	0.707*	62.88
217	Detroit White Lead Works, Detroit, Mich.	....	25.53	30.00	0.61	1.00	64.37
251	Devoe & Raynolds Co., New York	....	30.60	....	0.48	....	64.65
311	Merrimac Chemical Co., Boston, Mass.	....	29.80	....	0.83	....	62.75
227	Niagara Sprayer Co., Middleport, N. Y.	....	29.75	25.00	0.66	1.50	64.38
246	Niagara Sprayer Co,. Middleport, N. Y.	....	31.80	25.00	0.66	1.50	64.02
260	Sherwin-Williams, New York	....	31.60	30.00	0.76	1.00	62.95
265	Sherwin-Williams, New York	....	31.90	30.00	0.62	1.00	63.55
271	Toledo Rex Spray Co., Toledo, Ohio	....	30.40	30.00	0.76	1.00	64.00
307	Dr. Williams Fly & Insect Destroyer Co., Madrid, N. Y.	....	30.40	30.00	0.55	....	63.70
	PASTE.						
234	Ansbacher Insecticide Co., New York	46.49	17.03	15.00	0.32	0.50	34.94
250	Jas. A. Blanchard, New York	49.12	15.94	12.50	0.35	0.75	33.44
219	Dow Chemical Co., Midland, Mich.	48.47	16.18	15.00	0.46	0.75	34.05
229	Grasselli Chemical Co., Cleveland, Ohio	47.70	15.92	13.50	0.26	0.50	33.65
252	Grasselli Chemical Co., Cleveland, Ohio	48.64	16.92	15.00	0.33	0.50	33.96
233	Merrimac Chemical Co., Boston, Mass.	49.77	15.48	12.50	0.17	0.75	31.96
304	Niagara Sprayer Co., Middleport, N. Y.	50.09	15.08	15.00	0.52	0.75	32.34
270	Toledo Rex Spray Co., Toledo, Ohio	50.91	15.21	15.00	0.37	0.75	31.56

*Figured from 0.5% metallic As.

PARIS GREEN.

Twenty-one samples of Paris green were collected. The results are given in the following table and it will be seen that the samples from different manufacturers differ only slightly. The weight of all samples in original packages was in excess of that guaranteed. In every respect the samples comply with the legal standard.

One sample of Paris green paste and four samples of Paris green and gypsum mixture were collected and analyzed.

Number.	Manufacturer.	Arsenious Oxide (As_2O_3).				Copper Oxide (CuO).
		Total.		Soluble.		
		Found.	Guaranteed.	Found.	Guaranteed less than.	
		%	%	%	%	%
232	A. B. Ansbacher & Co., New York	56.27	55.00	2.07	3.5	29.4
279	A. B. Ansbacher & Co., New York	56.40	55.00	1.28	3.5	30.3
221	E. J. Barry, New York	55.08	50.00	1.48	3.5	30.6
208	Jas. A. Blanchard Co., New York	56.27	50.00	2.17	3.5	31.4
259	Jas. A. Blanchard Co., New York	56.65	50.00	1.68	3.5	29.2
181	Jas. A. Blanchard Co., New York	56.77	50.00	1.86	3.5	30.8
211	Carpenter-Udell Chemical Co., Grand Rapids, Mich	56.65	50.00	1.58	3.5	29.3
248	Carpenter-Udell Chemical Co., Grand Rapids, Mich	56.40	50.00	2.07	3.5	30.8
224	Corona Chemical Co., Milwaukee, Wis	55.15	50.00	2.37	3.5	30.3
241	Corona Chemical Co., Milwaukee, Wis	56.52	50.00	2.27	3.5	31.5
215	Devoe & Raynolds Co., New York and Chicago	57.62	50.00	1.58	3.5	31.3
249	Devoe & Raynolds Co., New York and Chicago	56.52	50.00	1.78	3.5	29.2
244	Morris Herrmann & Co., Chicago	57.15	50.00	1.25	3.5	29.7
255	Morris Herrmann & Co., Chicago	56.27	50.00	1.19	3.5	29.8
267	Morris Herrmann & Co., Chicago	56.27	50.00	1.87	3.5	29.2
256	Fred L. Lavanburg, New York	56.90	50.00	1.86	3.5	30.1
258	Fred L. Lavanburg, New York	55.77	50.00	1.28	3.5	29.5
228	Fred L. Lavanburg, New York	56.15	50.00	1.78	3.5	30.8
225	Sherwin-Williams Co., Chicago	56.77	50.00	1.68	3.5	29.2
230	Sherwin-Williams Co., Chicago	56.03	....	2.17	....	30.7
266	Sherwin-Williams Co., Chicago	56.52	50.00	2.17	3.5	29.4

No.	PARIS GREEN PASTE.	%	%	%	%	%	Water, %.
301	International Color & Chemical Co., Inc., Detroit, Mich	42.96	24.99*	1.10	1.74‡	23.4	22.16

*Computed from 18.93% metallic arsenic.
‡Computed from 1.32% metallic arsenic.

PLASTER—PARIS GREEN MIXTURES.

Number.	Manufacturer.	Arsenious Oxide.	
		Total.	Guaranteed.
		%	
206	Curtis Bros., Reed City, Mich	3.21	No guarantee.
205	H. J. Crocker, Reed City, Mich	3.21	No guarantee.
204	Earl Slawson, Greenville, Mich	3.33	No guarantee.
274	Michigan Gypsum Co., Grand Rapids, Mich	0.865	0.485

BORDEAUX MIXTURE.

Three samples of dry Bordeaux mixture and two samples of the paste form were obtained. These were found to vary considerably both as to the amount of copper contained and as to the directions for use. When these mixtures are used according to directions it is found that the amount of copper, calculated as copper sulfate, would vary from 1.1lb to 2.5lb for 50 gallons of solution. This variation may account for the difference in the results obtained from their use.

Number.	Manufacturer.	Water.	Copper (Cu).	
			Found.	Guaranteed.
	Dry Powder.	%	%	%
253	Ansbacher Insecticide Co., Inc., New York, "Quick Death"	....	14.65	12.0
254	Sherwin-Williams Co., Chicago, "Fungi-Bordo"	....	12.74	11.0
261	Sherwin-Williams Co., Chicago, "Fungi-Bordo"	....	13.00	11.0
	Paste.			
297	Jas. A. Blanchard, New York, "Lion Brand"	76.84	4.79	4.0
213	Carpenter Udell Chemical Co., Grand Rapids, Mich., "Imperial Brand"	63.72	7.68	....

BORDEAUX-ARSENATE MIXTURES.

Six samples of Bordeaux-arsenate mixture were obtained. In two of the samples, 218 and 214, the amounts of arsenic found are slightly below the amounts claimed but in all other respects the guarantees are satisfied.

In all of the samples the amount of arsenic is considerably in excess of the copper as compared with the amount usually recommended for adding to home-made Bordeaux.

When these materials are used according to the printed directions 50 gallons of the prepared spray would contain less than one pound of copper, expressed as copper sulfate, and from 1½ to 2 pounds of lead arsenate. Home-made Bordeaux as usually prepared contains from 2 to 4 pounds of copper sulfate in 50 gallons and when arsenate of lead is used it is added at the rate of 2 to 5 pounds to 50 gallons of solution.

Number.	Manufacturer.	Water.	Arsenic Oxide.				Metallic Copper.		Lead Oxide.
			Total.		Soluble.				
			Found.	Guaranteed.	Found.	Guaranteed less than.	Found.	Guaranteed.	
		%	%	%	%	%	%	%	%
269	Ansbacher Chemical Co., New York, "Adheso"—"Green label"	44.28	11.37	....	0.24	....	5.93	4-4.5	26.32
236	Ansbacher Chemical Co., New York, "Adheso"—"Green label"	49.87	10.48	8.39-9.25	0.40	0.50	4.22	3.75-4.25	25.92
214	Ansbacher Chemical Co., New York, "Adheso"—"Green label"	59.10	7.87	8.39-9.75	0.26	0.77*	4.46	4-4.5	19.79
218	Ansbacher Chemical Co., New York, "Adheso"—"Orange label"	58.03	8.71	8.8-9.3	0.33	0.77*	3.12	2.8-2.9	20.71
275	Bowker Insecticide Co., Boston, "Pyrox"	69.17	6.64	5.25	0.19	0.75	3.22	1.5	13.60

*Computed from 0.5% metallic arsenic.

TOBACCO PRODUCTS.

Seven samples of tobacco products were collected. In four of the samples the amounts of nicotine found were slightly below the guarantees but the deficiences are so small as to be negligible.

Number.	Manufacturer.	Nicotine.	
		Found.	Guaranteed.
222	Sterling Chemical Co., Cambridge, Mass., "Sterlingworth Powdered Tobacco"	0.693	0.35
235	F. A. Thompson & Co., Detroit, Mich., "Rose Nicotine"	11.78	10.00
273	F. A. Thompson & Co., Detroit, Mich., "Rose Nicotine"	9.93	10.00
280	F. A. Thompson & Co., Detroit, Mich., "Rose Nicotine"	10.29	10.00
210	Kentucky Tobacco Product Co., Louisville, Ky., "Blackleaf 40"	39.76	40.00
245	Kentucky Tobacco Product Co., Louisville, Ky., "Blackleaf 40"	39.96	40.00
268	Kentucky Tobacco Product Co., Louisville, Ky., "Blackleaf 40"	39.90	40.00

SMUT REMEDIES.

(Formaldehyde Solutions.)

Four samples of smut remedies representing three manufacturers were collected. The active ingredient of all was found to be formaldehyde, the amounts found varying from 17.78% to 30.00%. In every case other substances had been added, such as coloring matter, tar oil, etc., presumably to, partially at least, disguise the formaldehyde. In no case do the added ingredients enhance the fungicidal properties of the formaldehyde. Although there is a variation of nearly 100 per cent in the amount of formaldehyde contained in these preparations, the directions for their use are the same in every case.

Formaldehyde, 40% strength, can be bought for $1.50 per gallon.

Number.	Brand.	Manufacturer.	Formaldehyde.
			%
282	Anti-Smut	Anti-Smut Chemical Co., North Adams, Mich	21.37
290	Bud's Smuticide	Albion Chemical Works, Albion, Mich	30.00
223	Dr. Lapes' Smut Destroyer (two samples)	Dr. Lape Veterinary Co., Adrian, Mich	18.91 17.78

LICE POWDERS.

Eight samples of lice powders were collected and examined. Seven were found to contain nicotine and naphthaline (the last named being the active constituent of moth balls) and six contained sulfur. Pyrethrum was present in three of the samples.

All of these preparations would probably prove effective against lice when used in a closed chamber but their efficiency would be greatly reduced when used in the open or in a large room.

Number.	Manufacturer.	Nicotine.		Sulfur.		Napthalin.	Pyrethrum.
		Found.	Guaranteed.	Found.	Guaranteed.		
276	Salvet Lice Powder, Feil Mfg. Co., Cleveland, O.	0.09	....	41.48	......	Present...	....
308	Fleck's Lice Powder, J. J. Fleck, Tiffin, O.	0.14	0.01	....	......	Present...	Present.
288	Dr. Hess Instant Louse Killer, Dr. Hess & Clark, Ashland, O.	0.07	0.10	....	......	Present...	....
309	Chicure Lice Powder, King Remedy Co., Rochester, N. Y.	0.19	10.0	24.70	20.0	Present...	Present.
293	Pratts' Lice Killer, Pratt Food Co., Chicago, Ill.	0.46	0.34	4.81	......	Present...	Present.
238	Seneca Lice Powder, The Seneca Co., Tiffin, O.	......	....	9.51	......	Present...	....
286	Zenoleum Powder, Zenner Disinfectant Co., Detroit, Mich.	0.39	0.25	11.70	10.0	Present...	....
294	Rust's Powder, Wm. Rust & Son Co., New Brunswick, N. J.	0.90	0.40	12.23	7.50	....	....

PYRETHRUM POWDERS.

Of the four samples examined pyrethrum was found to be the active ingredient. This is a well known and effective insect powder but it loses its strength rapidly on exposure to the air, consequently it should always be kept in air-tight receptacles.

No.	Name of sample and manufacturer.	
278	Black Flag Insect Powder, Langdon & Co., Baltimore, Md.	Contains pyrethrum as active ingredient.
298	"El Vampiro" Allair Woodward & Co., Peoria, Ill.	Contains pyrethrum as active ingredient.
291	Shure Shot Roach Powder, American Druggist Syndicate, New York.	Contains pyrethrum as active ingredient.
300	Elkay's Ant, Bug and Roach Powder, United Drug Co., Boston.	Contains pyrethrum as active ingredient.

MISCELLANEOUS MATERIALS.

299. Peterman's Ant Food. Manufactured by Wm. Peterman, New York City. Guaranteed to contain 65-75% sodium fluorid. Found, sodium fluorid 68.87%, sugar, and other substances to act as bait.

295. Powdered Hellebore. Manufactured by Jas. A. Blanchard, New York City. Moisture 10.49%. Ash 10.86%. All tests show the sample to be pure hellebore.

306. Arsite. Manufactured by Morris Herrmann & Co., New York City. Guaranteed to contain total arsenic (expressed as metallic arsenic) 28.8%. Soluble arsenic 28.8%. Found total arsenic (expressed as metallic arsenic) 30.15%. Completely soluble. Sample is a solution of ordinary white arsenic.

305. Calite. Manufactured by Morris Herrmann & Co., New York City. Guaranteed to contain water 66%. Total arsenic (expressed as metallic arsenic) 11.4%. Arsenic in water soluble forms ½ to 1%. Found, water 66.27%. Total arsenic (expressed as metallic arsenic) 12.70%. Soluble arsenic (expressed as metallic arsenic) 0.30%. Sample is calcium arsenate paste.

292. London Purple. Manufactured by Hemmingway's London Purple Co., New York City. Guaranteed to contain total arsenic (expressed as metallic arsenic) 21%, water soluble arsenic 3%. Found, total arsenic (expressed as metallic arsenic) 15.55%, arsenic in water soluble form 3.17%. Sample is composed of calcium arsenite 30.48% and calcium arsenate 7.67%.

310. "All-in One" Spray. Manufactured by Buffalo Specialty Co., Buffalo, N. Y. Guaranteed to contain total arsenic (expressed as metallic arsenic) 4%, arsenic in water soluble form 0.50%. Found, total arsenic (expressed as metallic arsenic) 5.60%. Soluble arsenic 0.54%. Sample is apparently lead arsenate with materials added to act as bait for insects.

303. Slug Shot. Manufactured by Hammond Slug Shot Works, Beacon, N. Y. Guaranteed to contain sulfur 6%, arsenic (expressed as metallic arsenic) 0.785%, copper sulfate 1%, nicotine a trace, crude carbolic acid 0.40%. Sample contains total arsenic (expressed as metallic arsenic) 1.30%, sulfur 7.26%. Qualitative tests showed copper and carbolic acid to be present.

209 Bug Death.
263 Bug Death. } Manufactured by Danforth Chemical Co., Leominster, Mass. Guaranteed to contain zinc oxid 47%, lead oxid 5%. Results found, sample 209, lead oxid 5.24%, zinc oxid 49.59%. Sample 263, lead oxid 5.39%, zinc oxid 49.22%.

257. Bug-i-cide. Sold by Harris Bros., Muskegon, Mich.

289. Bug-i-cide. Sold by Battlement Drug Co., Benton Harbor, Mich. No guarantee on either sample. Examination showed them to be composed of benzine, kerosene, and other light oils. Sample 257 contains red coloring matter.

302. Sulfo-Tobacco Soap. Manufactured by Larkin Co., Buffalo, N. Y. Guaranteed to contain 88.5% soap, 0.50% nicotine and 1% sodium sulfid. Nicotine only was determined, the result being 0.24%.

285. Rawleigh's Stock Dip and Disinfectant. Manufactured by The W. T. Rawleigh Co., Freeport, Ill. Guaranteed to contain

Coal Tar Hydrocarbons	52.4%
Coal Tar Phenols	15.4%

This is an ordinary coal tar dip made according to the usual formula using rosin, caustic soda, coal tar oil and phenols. The composition as found is as follows:

Pyridine bases	1.04%
Hydrocarbons	71.93%
Rosin acids	4.35%
Phenols	9.42%

Materials of this kind have been successfully used for a long time as cattle dips and disinfectants and are well and favorably known.

During the past season, however, this particular material was advertised and sold as a remedy for San José scale.

287. Zenoleum Disinfectant. Manufactured by Zenner Disinfectant Co., Detroit, Mich. This is very similar to No. 285, the analysis being as follows:-

Pyridine bases	2.55%
Hydrocarbons	76.80%
Rosin acids	2.43%
Phenols	8.83%

239. Carboline Lice Killer. Manufacturers name not given. Sold by H. W. Ogden, Shelby, Mich. This is apparently an ordinary coal tar

oil from which most of the lighter oils have been extracted leaving a large amount of heavy tar oil. Contains some creosote oil.

East Lansing, Mich., June 30, 1916.

MICHIGAN WEATHER SERVICE OPERATIONS FOR YEAR ENDING JUNE 30TH, 1916.

The general policy of the service has continued without any material change during the past year. The number of cooperative observation stations at the close of the year was 129. Besides this there are 12 regular Weather Bureau stations, making a total of 141 places where meteorological records are maintained.

The work of the cooperative observers is as a whole very commendable. The service has a number of men who have taken observations for over 25 years; more that have reported for 20 years or more, and a large number that have been cooperating for 10 years or more.

All equipment is of standard type and each station is fully equipped with a regulation outfit.

I can repeat with more emphasis, my remarks of one year ago in stating that the records are more useful and the demand for them becoming greater as time passes.

The agricultural interests are beginning to learn that in a great measure they must adapt their crops not only to the soil—but to the climate, instead of trying to adapt the climate to the crops. This is paricularly true in the northern portions of the Lower Peninsula. Many farmers are trying to raise crops up there that the Weather Bureau records surely indicate cannot as a rule be brought to maturity.

Our records of the average last killing frost in spring and the first killing frost in autumn, mark the boundaries of the growing season, and are being studied more and more.

With the extension of the rural telephone, the farmer is also learning to use more than ever before, the forecasts of the Weather Bureau. When it is remembered that 85 per cent or more of these forecasts are correct, it must be admitted that in the long run they are of immense practical value during the planting and harvesting seasons, and of great interest during the growing period.

The time is surely coming when man will study all factors with care before endeavoring to employ nature to give him a livelihood. Large tracts of land in the northern part of the State will yield much hay, much fodder corn and much oats, which in turn can be used to advantage in the stock and dairying business. It has always amazed me that Michigan will import butter and cheese from Denmark, when our own State offers such great possibilities for making butter and cheese.

Active cooperation has been rendered to the Grand Rapids & Indiana Railroad Company in connection with their demonstration farms at Howard City, and some other northerly points. This railroad corporation is endeavoring to show what and how profitable crops can be grown, not only in the northerly parts of the State, but in the light sandy soil of which there is so much. They have selected typical land, cleared it, plowed it and planted it, keeping careful record of the cost and all of their results, in an endeavor to show the world that there are thousands of acres of land in northern Michigan which can be made valuable agriculturally.

The water power interests of Michigan continue to develop and many possibilities and probabilities are as yet untouched. The short, quick and even flowing streams of northern Michigan running both east and west into Lake Michigan and Lake Huron, have great hydro-electric possibilities. Many of the principal rivers are already highly developed and in the development work the Weather Bureau records are of the greatest value.

Numberless railroad freight claims are adjusted by the help of the Weather Bureau records. Rainfall, temperature and wind direction records are in constant demand in various civil court proceedings ranging from leaky roofs to murder. Our printed reports are asked for by many outside interests who are contemplating some business connections in Michigan.

The weekly weather and crop statements issued from this office are widely sought for and afford to the farmer a reliable source of information regarding crop conditions in all sections of the State. I think this information is of more value to the farmer than the average man of the country realizes. He is raising crops to sell and general information about crops similar to his own, not only in other parts of the State, but in other parts of the country, should help him as to the time of marketing his own.

C. F. SCHNEIDER,
Meteorologist.

Dated at Grand Rapids, Mich., June 30, 1916.

METEOROLOGICAL TABLES.

METEOROLOGICAL TABLES.

Monthly Meteorological Summary, Lansing, Michigan, July, 1915.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	84	57	70	0.74	Partly cloudy	67
2	80	60	70	0.01	Partly cloudy	49
3	75	52	64	0	Partly cloudy	89
4	70	51	60	0.41	Cloudy	12
5	65	50	58	0	Partly cloudy	56
6	76	47	62	0	Partly cloudy	72
7	68	60	64	1.63	Cloudy	5
8	75	52	64	0.19	Partly cloudy	70
9	80	49	64	0	Partly cloudy	80
10	80	57	68	0	Partly cloudy	89
11	81	64	72	0	Partly cloudy	56
12	85	64	74	0	Partly cloudy	81
13	85	58	72	0	Clear	100
14	83	62	72	0.03	Cloudy	39
15	79	68	74	0.24	Cloudy	3
16	87	66	76	0	Partly cloudy	80
17	84	63	74	0	Clear	97
18	81	61	71	0.78	Partly cloudy	55
19	74	59	66	0	Partly cloudy	36
20	71	54	62	0.07	Partly cloudy	54
21	71	50	60	0.16	Partly cloudy	66
22	77	48	62	0	Clear	96
23	79	50	64	0	Clear	96
24	79	57	68	0.23	Cloudy	21
25	76	59	68	0.06	Cloudy	28
26	78	58	68	0	Partly cloudy	35
27	71	58	64	0.06	Cloudy	0
28	76	64	70	0.14	Cloudy	20
29	79	62	70	0.15	Cloudy	11
30	83	69	76	0	Partly cloudy	54
31	84	67	76	0.27	Partly cloudy	51

Mean highest temperature	77.9
Mean lowest temperature	57.9
Mean temperature for month	67.9
Total precipitation for month	5.17
WEATHER	
Number days clear	4
Partly cloudy	18
Cloudy	9
With 0.01 or more of precipitation	16
SUNSHINE	
Number hours sunshine	250.4
Possible hours sunshine	464.9
Percentage of possible	54

This month since 1864.		
Year.	Mean temperature.	Total precipitation.
1864	74.5	1.25
1865	65.6	3.91
1866	71.7	4.19
1867	71.6	1.78
1868	77.2	1.11
1869	70.4	5.77
1870	74.4	8.02
1871	70.6	3.10
1872	74.9	3.36
1873	70.8	5.12
1874	72.0	2.56
1875	69.7	2.42
1876	72.5	2.10
1877	71.4	2.25
1878	73.0	2.96
1879	74.0	2.19
1880	68.0	6.27
1881	73.1	1.81
1882	67.5	2.32
1883	68.9	11.27
1884	68.0	2.60
1885	72.7	2.52
1886	70.7	0.65
1887	75.5	1.50
1888	70.5	2.40
1889	70.2	3.41
1890	71.1	0.92
1891	65.3	1.88
1892	70.3	2.00
1893	71.5	1.86
1894	73.2	0.86
1895	70.5	1.47
1896	71.8	6.73
1897	73.8	8.49
1898	70.0	1.34
1899	69.8	2.11
1900	69.6	4.15
1901	74.2	5.08
1902	70.6	7.13
1903	67.9	3.79
1904	69.2	1.97
1905	69.8	5.75
1906	70.8	2.23
1907	70.0	4.30
1908	73.2	1.03
1909	70.0	2.56
1910	71.0	1.53
1911	71.3	1.65
1912	69.6	5.06
1913	70.8	2.85
1914	71.0	1.65
1915	67.9	5.17

BAROMETER—Mean, 29.93 inches; highest, 30.20 inches, on 26th; lowest, 29.62 inches, on 4th.

TEMPERATURE—Highest, 87°, on 16th; lowest, 47°, on 6th; greatest daily range, 31°, on 9th; least daily range, 8°, on 7th; normal for month, 70.9°; excess or deficiency this month, −3.0°; accumulated excess or deficiency since January 1st, −193°; average daily, same period, −0.9°; highest in 30 years, 102°; lowest, 37°.

PRECIPITATION (in inches)—Total amount, 5.17; normal, 3.22; excess or deficiency this month; +1.95; since January 1st, −1.82; greatest amount in any 24 hour period, 1.82, on 7th and 8th; total snowfall, 0.0 inches.

WIND—Prevailing direction, southwest; total movement, 2,889 miles; average hourly velocity, 3.9 miles; maximum velocity, 18, from the southeast, on 1st.

DATES OF—Auroras, 0; dense fog, 16; hail, 0; sleet, 0; thunderstorms, 1, 2, 7, 18, 21, 28; halos: solar, 9; lunar, 0; frost: killing, 0; heavy, 0; light, 0.

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, August, 1915.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	86	65	76	0.03	Partly cloudy	81
2	75	64	70	0.21	Cloudy	8
3	80	62	71	0.19	Cloudy	20
4	70	58	64	0.03	Cloudy	5
5	60	55	58	0.16	Cloudy	1
6	69	57	63	0.10	Cloudy	15
7	78	54	66	0	Cloudy	46
8	80	58	69	0	Partly cloudy	82
9	78	56	67	0	Clear	98
10	81	55	68	0	Partly cloudy	84
11	70	58	64	0.01	Cloudy	13
12	69	61	65	0.97	Cloudy	0
13	80	60	70	0.09	Partly cloudy	62
14	79	58	68	0.03	Cloudy	41
15	83	59	71	0	Clear	100
16	83	62	72	1.63	Partly cloudy	73
17	67	46	56	0	Partly cloudy	63
18	73	42	58	0	Clear	100
19	76	47	62	0	Clear	100
20	73	49	61	0	Cloudy	54
21	65	60	62	1.16	Cloudy	0
22	78	56	67	0	Clear	79
23	81	56	68	0	Partly cloudy	87
24	73	58	66	0.02	Cloudy	36
25	66	51	58	0	Partly cloudy	47
26	63	45	54	0	Clear	87
27	67	38	52	0	Clear	99
28	72	41	56	0	Clear	94
29	69	48	58	0	Cloudy	23
30	60	42	51	0	Partly cloudy	59
31	68	40	54	0	Clear	100

Mean highest temperature	73.3
Mean lowest temperature	53.6
Mean temperature for month	63.4
Total precipitation for month	4 63
WEATHER	
Number days clear	9
Partly cloudy	9
Cloudy	13
With 0.01 or more of precipitation	13
SUNSHINE	
Number of hours sunshine	242 3
Possible hours sunshine	440.7
Percentage of possible	56

This month since 1864.		
Year.	Mean temperature.	Total precipitation.
1863	....	3.00
1864	70.7	0.39
1865	65.8	3.38
1866	62.6	3.44
1867	69.8	1.74
1868	70.3	2.42
1869	70.6	4.85
1870	70.1	4.53
1871	71.2	1.42
1872	71.2	4.18
1873	69.5	0.80
1874	69.4	1.28
1875	65.5	1.47
1876	71.6	1.28
1877	68.5	6.57
1878	70.2	1.85
1879	70.0	1.61
1880	68.6	6.02
1881	72.7	1.63
1882	69.5	5.72
1883	64.9	0.18
1884	66.9	1.30
1885	63.6	6.75
1886	69.3	4.69
1887	68.0	0.89
1888	67.6	1.87
1889	68.6	0.68
1890	65.4	3.60
1891	67.9	4.82
1892	68.3	5.12
1893	68.1	0.56
1894	68.8	0.00
1895	71.2	4.64
1896	70.0	4.73
1897	65.9	1.69
1898	69.0	2.73
1899	71.4	0.70
1900	73.3	2.98
1901	68.4	2.49
1902	64.2	0.68
1903	64.3	6.73
1904	65.9	3.26
1905	69.6	3.92
1906	73.5	4.35
1907	65.5	2.87
1908	68.4	3.99
1909	71.0	1.61
1910	68.2	1.76
1911	68.2	1.48
1912	65.7	2.19
1913	69.4	5.60
1914	68.9	3.33
1915	63.4	4.63

BAROMETER—Mean, 29.97 inches; highest, 30.34 inches, on 18th; lowest, 29.58 inches, on 21st.

TEMPERATURE—Highest, 86°, on 1st; lowest, 38°, on 27th; greatest daily range, 31°, on 18th; least daily range, 5°, on 21st; normal for month, 68.4°, excess or deficiency this month, −5.0°; accumulated excess or deficiency since January 1, −347°; average daily, same period, −1.4°, highest in 30 years, 99°, lowest, 32°.

PRECIPITATION (in inches)—Total amount, 4.63; normal, 2.63; excess or deficiency this month, +2.00; since January 1, +0.18. greatest amount in any 24 hour period, 1.63, on 16th; total snowfall, 0.0 in.

WIND—Prevailing direction, northeast; total movement, 3,290 miles; average hourly velocity, 4.4 miles; maximum velocity, 20, from the northwest, on 16th.

DATES OF—Auroras, 0; dense fog, 29; hail, 16; sleet, 0; thunderstorms 7, 8, 12, 13, 14, 16, 24; halos: solar 14, 20, 26; lunar, 0; frost: killing, 0; heavy, 0; light, 18, 27, 31.

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, September, 1915.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	77	46	62	0	Clear	100
2	83	46	64	0	Clear	100
3	82	54	68	0	Partly cloudy	48
4	76	58	67	0.01	Cloudy	8
5	68	61	64	1.45	Cloudy	0
6	64	61	62	0.68	Cloudy	0
7	79	61	70	0.13	Partly cloudy	34
8	85	64	74	0.52	Clear	79
9	76	57	66	0	Partly cloudy	30
10	78	50	64	0.94	Partly cloudy	56
11	72	62	67	0	Cloudy	39
12	87	61	74	0.73	Partly cloudy	54
13	86	66	76	0	Clear	98
14	89	71	80	0	Clear	100
15	78	64	71	0	Cloudy	51
16	85	64	74	0.20	Partly cloudy	62
17	77	58	68	0	Partly cloudy	73
18	74	56	65	0.04	Partly cloudy	28
19	75	55	65	0	Clear	94
20	76	51	64	0.72	Cloudy	46
21	59	41	50	0	Partly cloudy	72
22	65	34	50	0	Clear	100
23	67	42	54	0	Partly cloudy	64
24	72	55	64	0	Partly cloudy	79
25	77	53	65	0	Partly cloudy	58
26	67	43	55	1.13	Cloudy	7
27	54	39	49	0	Cloudy	21
28	58	36	47	0	Clear	99
29	63	33	48	0	Clear	100
30	64	36	50	0	Partly cloudy	87
31						

Mean highest temperature	73.8
Mean lowest temperature	52.6
Mean temperature for month	63.2
Total precipitation for month	6.55

WEATHER

Number days clear	9
Partly cloudy	13
Cloudy	8
With 0.01 or more of precipitation	11

SUNSHINE

Number hours sunshine	222.4
Possible hours sunshine	374.8
Percentage of possible	59

This month since 1864.		
Year.	Mean temperature.	Total precipitation.
1863	....	0.89
1864	59.6	3.53
1865	67.7	4.79
1866	55.8	5.80
1867	56.6	1.42
1868	58.8	2.95
1869	63.5	1.43
1870	63.7	2.85
1871	59.1	0.79
1872	62.0	5.21
1873	67.4	3.50
1874	62.8	1.27
1875	58.5	2.89
1876	56.3	3.65
1877	61.3	1.38
1878	63.2	3.41
1879	56.2	3.19
1880	55.8	3.10
1881	69.7	2.91
1882	59.9	0.67
1883	56.4	2.34
1884	65.1	3.34
1885	58.9	3.75
1886	62.1	5.40
1887	58.9	4.72
1888	57.8	1.89
1889	61.2	0.79
1890	57.7	1.67
1891	65.1	1.10
1892	60.8	2.17
1893	58.4	1.84
1894	63.7	2.59
1895	66.6	0.85
1896	57.6	6.73
1897	62.9	0.80
1898	63.3	3.00
1899	57.0	2.14
1900	63.2	0.89
1901	61.7	1.67
1902	58.7	5.88
1903	61.0	2.86
1904	62.0	2.35
1905	63.8	3.21
1906	67.5	0.76
1907	61.8	4.68
1908	66.4	0.65
1909	60.4	1.51
1910	60.2	2.74
1911	61.5	5.05
1912	62.7	3.33
1913	61.0	1.53
1914	60.3	2.65
1915	63.2	6.55

BAROMETER—Mean, 30.04 inches; highest, 30.38 inches, on 2nd; lowest, 29.57 inches, on 20th.

TEMPERATURE—Highest, 89°, on 14th; lowest, 33°, on 29th; greatest daily range, 37°, on 2nd; least daily range, 3°, on 6th; normal for month, 61.6°; excess or deficiency this month, +1.6°; accumulated excess or deficiency since January 1st, −301°; average daily, same period, −1.1°; highest in 30 years, 99°; lowest, 21°.

PRECIPITATION (in inches)—Total amount, 6.55; normal, 2.62; excess or deficiency this month, +3.93; since January 1st, +4.11; greatest amount in any 24 hour period, 1.96, on 5th and 6th; total snowfall, 0.0 inches.

WIND—Prevailing direction, southwest; total movement, 3,553 miles; average hourly velocity, 4.9 miles; maximum velocity, 19; from the northwest, on 26th.

DATES OF—Auroras, 0; dense fog, 0; hail, 0; sleet, 0; thunderstorms, 8, 10, 12, 14, 16, 20, 23; halos: solar, 25, 30; lunar, 24; Frost: killing, 0; heavy, 29; light, 22, 28, 30.

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, October, 1915.

Date.	Temperature. Highest.	Temperature. Lowest.	Temperature. Mean.	Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
1	53	48	50	0.15	Cloudy	0
2	66	47	56	0	Partly cloudy	48
3	76	50	63	0	Partly cloudy	66
4	69	50	60	0.03	Cloudy	36
5	51	43	47	0.01	Cloudy	25
6	54	42	48	0	Partly cloudy	36
7	52	38	45	0.01	Cloudy	19
8	43	37	40	0.02	Cloudy	0
9	46	29	38	0	Cloudy	27
10	54	28	41	0	Partly cloudy	94
11	69	46	58	0	Partly cloudy	100
12	68	46	57	0	Partly cloudy	97
13	64	51	58	0.12	Cloudy	5
14	62	50	56	0	Cloudy	14
15	63	41	52	0	Clear	74
16	61	36	48	0	Partly cloudy	70
17	64	41	52	0.06	Cloudy	70
18	65	54	60	0.30	Cloudy	26
19	65	48	56	0	Partly cloudy	55
20	73	46	60	0	Clear	100
21	65	36	50	0	Clear	100
22	63	34	48	0	Clear	100
23	54	32	43	0	Clear	95
24	55	28	42	0	Clear	85
25	67	44	56	0	Clear	100
26	60	36	48	0	Partly cloudy	90
27	56	33	44	0	Clear	77
28	68	41	54	0	Partly cloudy	96
29	58	40	49	0	Partly cloudy	65
30	65	34	50	0	Clear	100
31	69	41	55	0	Cloudy	77

Mean highest temperature	61.2
Mean lowest temperature	41.0
Mean temperature for month	51.1
Total precipitation for month	0.70

WEATHER

Number days clear	9
Partly cloudy	11
Cloudy	11
With 0.01 or more of precipitation	8

SUNSHINE

Number hours sunshine	212.1
Possible hours sunshine	341.9
Percentage of possible	62

This month since 1864.

Year.	Mean temperature.	Total precipitation.
1863	....	1.04
1864	45.7	1.86
1865	46.5	2.76
1866	49.5	3.57
1867	50.6	2.11
1868	45.2	1.11
1869	40.8	1.72
1870	52.5	2.29
1871	53.9	1.43
1872	47.4	0.67
1873	44.7	1.91
1874	49.1	0.49
1875	42.9	5.81
1876	43.7	1.26
1877	50.8	5.69
1878	48.3	1.99
1879	57.3	1.57
1880	46.2	2.84
1881	52.5	5.56
1882	52.7	2.64
1883	46.2	3.66
1884	50.9	5.73
1885	45.0	3.08
1886	52.4	0.95
1887	45.0	1.86
1888	45.7	3.00
1889	44.2	0.65
1890	49.1	4.56
1891	48.8	0.82
1892	48.3	0.78
1893	49.7	3.61
1894	49.8	1.91
1895	45.0	1.41
1896	44.6	1.06
1897	53.1	2.15
1898	49.6	3.55
1899	53.2	2.68
1900	56.6	2.77
1901	49.6	4.61
1902	49.6	1.53
1903	51.0	2.01
1904	48.6	1.90
1905	50.9	1.75
1906	49.2	2.36
1907	46.0	2.22
1908	51.6	0.82
1909	46.2	0.71
1910	51.8	2.27
1911	48.0	5.00
1912	50.4	3.44
1913	50.2	3.30
1914	54.6	2.81
1915	51.1	0.70

BAROMETER—Mean, 30.05 inches; highest, 30.50 inches, on 16th; lowest, 29.56 inches, on 31st.

TEMPERATURE—Highest, 76°, on 3rd; lowest, 28°, on 10th; greatest daily range, 31°, on 30th; least daily range, 5° on 1st; normal for month, 49.0°; excess or deficiency this month, +2.1°; accumulated excess or deficiency since January 1st, −236°; average daily, same period, −0.8°; highest in 30 years, 90°; lowest, 10°.

PRECIPITATION (in inches)—Total amount, 0.70; normal, 2.23; excess or deficiency this month, −1.53; since January 1st, +2.58; greatest amount in any 24 hour period, 0.36, on 17th and 18th; total snowfall, 0.0 inches.

WIND—Prevailing direction, southwest; total movement, 4,539 miles; average hourly velocity, 6.1 miles; maximum velocity, 24, from the southwest, on 26th.

DATES OF—Auroras, 0; dense fog, 0; hail, 0; sleet, 0; thunderstorms, 0; halos: solar 11, 12, 17, 28, 31; lunar, 24; frost: killing, 10; heavy, 0; light, 0.

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, November, 1915.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	64	41	52	0	Partly cloudy	56
2	51	28	40	0	Cloudy	4
3	47	26	36	0.03	Partly cloudy	97
4	59	38	48	0	Partly cloudy	73
5	44	32	38	0	Cloudy	5
6	51	31	41	0	Partly cloudy	67
7	62	37	50	0	Partly cloudy	100
8	71	42	56	0	Clear	91
9	51	33	42	0	Clear	100
10	50	31	40	0	Cloudy	13
11	66	45	56	0.60	Cloudy	11
12	51	32	42	0	Clear	100
13	50	31	40	0	Clear	100
14	51	30	40	0.04	Cloudy	61
15	34	27	30	0	Cloudy	27
16	34	24	29	0.12	Cloudy	8
17	43	26	34	0	Clear	91
18	46	31	38	0.31	Cloudy	14
19	44	34	39	0.31	Cloudy	0
20	39	32	36	0	Cloudy	8
21	34	28	31	0.02	Cloudy	1
22	31	25	28	0	Cloudy	0
23	34	26	30	0.05	Cloudy	0
24	41	27	34	0	Cloudy	53
25	60	38	49	0	Cloudy	17
26	60	50	55	0.03	Cloudy	32
27	50	38	44	0.04	Partly cloudy	51
28	43	32	38	0.44	Cloudy	1
29	32	25	28	0.22	Cloudy	22
30	30	22	26	0.02	Cloudy	24
31						

Mean highest temperature	47.4
Mean lowest temperature	32.1
Mean temperature for month	39.8
Total precipitation for month	2.23

WEATHER

Number days clear	5
Partly cloudy	6
Cloudy	19
With 0.01 or more of precipitation	13

SUNSHINE

Number hours sunshine	121.0
Possible hours sunshine	292.1
Percentage of possible	41

This month since 1864.		
Year.	Mean temperature.	Total precipitation.
1863	....	0.40
1864	37.9	4.12
1865	38.6	0.68
1866	37.9	2.60
1867	40.4	1.77
1868	36.8	2.44
1869	32.1	1.93
1870	38.4	0.91
1871	32.0	1.25
1872	29.8	0.98
1873	28.5	2.03
1874	35.0	1.61
1875	33.0	1.11
1876	36.3	0.91
1877	35.2	3.67
1878	36.3	2.16
1879	38.2	4.55
1880	27.5	2.32
1881	38.2	4.09
1882	36.3	1.83
1883	38.1	3.98
1884	34.1	1.84
1885	37.2	2.90
1886	33.9	1.48
1887	35.7	2.28
1888	38.5	3.12
1889	37.4	2.67
1890	39.1	2.30
1891	34.0	3.34
1892	34.2	1.84
1893	35.6	2.19
1894	32.5	0.97
1895	35.4	3.87
1896	37.1	1.05
1897	36.5	2.94
1898	33.1	2.72
1899	39.7	1.72
1900	35.3	5.10
1901	32.8	1.21
1902	43.0	2.46
1903	34.0	1.45
1904	40.0	0.04
1905	35.8	2.25
1906	37.0	2.66
1907	36.0	1.83
1908	38.2	1.82
1909	44.5	3.74
1910	34.0	1.37
1911	33.8	3.40
1912	38.6	2.86
1913	41.7	2.38
1914	37.6	1.40
1915	39.8	2.23

BAROMETER—Mean, 29.93 inches; highest, 30.44 inches, on 10th; lowest, 28.99 inches, on 19th.

TEMPERATURE—Highest, 71°, on 8th; lowest, 22°, on 30th; greatest daily range, 29°, on 8th; least daily range, 6°, on 22d; normal for month, 36.8°; excess or deficiency this month, +3.0°; accumulated excess or deficiency since January 1st, −151°; average daily, same period, −0.5°; highest in 30 years, 72°; lowest, 0°.

PRECIPITATION (in inches)—Total amount, 2.23; normal, 2.41; excess or deficiency this month, −0.18; since January 1st, +2.40; greatest amount in any 24 hour period, 0.66, on 28th and 29th; total snowfall, 7.6 inches.

WIND—Prevailing direction, southeast; total movement, 6,094 miles; average hourly velocity, 8.5 miles; maximum velocity, 25, from the southwest, on 11th.

DATES OF: Auroras, 5; dense fog, 0; hail, 0; sleet, 0; thunderstorms, 0; halos: solar, 3, 7, 14, 24; lunar, 17, 22; frost: killing, heavy, light (frosts not recorded).

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, December, 1915.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	33	23	28	0.03	Cloudy	9
2	32	19	26	0	Clear	82
3	32	14	23	0	Clear	67
4	31	11	21	0	Clear	100
5	33	20	26	0	Partly cloudy	48
6	32	15	24	0	Partly cloudy	87
7	35	14	24	0	Cloudy	0
8	36	31	34	0.01	Cloudy	8
9	31	20	26	0	Cloudy	48
10	28	15	22	0	Cloudy	63
11	28	15	22	0	Cloudy	5
12	28	22	25	0.17	Cloudy	0
13	32	20	26	0.03	Cloudy	36
14	23	14	18	0	Clear	97
15	30	11	20	0	Clear	100
16	32	16	24	0.04	Cloudy	7
17	35	29	32	0.02	Cloudy	0
18	32	22	27	0.01	Cloudy	0
19	26	20	23	0.02	Cloudy	1
20	21	18	20	0.02	Cloudy	0
21	27	18	22	0.03	Cloudy	24
22	38	22	30	0.01	Partly cloudy	53
23	39	33	36	0.05	Cloudy	0
24	33	30	32	0.32	Cloudy	0
25	31	11	21	0.15	Cloudy	50
26	29	13	21	0	Cloudy	39
27	32	22	27	0	Cloudy	7
28	26	8	17	0	Clear	100
29	30	11	20	0	Partly cloudy	49
30	29	20	24	0	Cloudy	60
31	35	23	29	0.10	Cloudy	7

Mean highest temperature	30.9
Mean lowest temperature	18.7
Mean temperature for month	24.8
Total precipitation for month	1.01

WEATHER

Number days clear	6
Partly cloudy	4
Cloudy	21
With 0.01 or more of precipitation	15

SUNSHINE

Number hours sunshine	104.0
Possible hours sunshine	280.8
Percentage of possible	37

This month since 1864.		
Year.	Mean temperature.	Total precipitation.
1863	....	1.71
1864	24.4	3.20
1865	26.7	1.43
1866	25.5	1.90
1867	25.3	1.34
1868	21.2	1.35
1869	28.2	2.11
1870	24.8	2.57
1871	21.1	1.76
1872	15.7	1.06
1873	29.5	3.02
1874	27.0	0.37
1875	31.6	2.80
1876	15.2	1.29
1877	36.6	1.03
1878	21.3	2.27
1879	27.5	3.55
1880	22.1	0.85
1881	34.3	1.75
1882	24.8	0.88
1883	26.4	1.28
1884	24.7	4.15
1885	27.8	2.14
1886	19.7	1.56
1887	27.3	3 32
1888	30.4	1.20
1889	36.8	2.61
1890	26.4	1.12
1891	34.6	1.47
1892	25.6	1.52
1893	27.6	2.28
1894	30.1	0.93
1895	28.5	5.39
1896	28.1	0.80
1897	25.6	2.02
1898	21.8	1.42
1899	25.0	1.51
1900	26.7	0.50
1901	21.6	3.00
1902	24.8	2.89
1903	19.7	1.75
1904	21.7	1.42
1905	30.2	2.54
1906	26 8	1 85
1907	22.7	4.19
1908	26.4	2.08
1909	23.0	2.91
1910	21.6	1.28
1911	31.1	1.58
1912	31.0	1.20
1913	31.8	0.55
1914	21.6	1.57
1915	24.8	1.01

BAROMETER—Mean, 30.04 inches; highest, 30.54 inches, on 6th; lowest, 29.47 inches, on 17th.

TEMPERATURE—Highest, 39°, on 23rd; lowest, 8°, on 28th; greatest daily range, 21°, on 7th; least daily range, 3°, on 20th; Normal for month, 26.8°; excess or deficiency this month, −2.0°; accumulated excess or deficiency since January 1st, −211°; average daily, same period, −0.6°; highest in 30 years, 62°; lowest, −24°.

PRECIPITATION (in inches)—Total amount, 1.01; normal, 2.08; excess or deficiency this month, −1.07; since January 1st, +1.33; greatest amount in any 24 hour period, 0.47, on 24th and 25th; total snowfall, 11.0 inches.

WIND—Prevailing direction, southwest; total movement, 4,814 miles; average hourly velocity, 6.5 miles; maximum velocity, 21, from the northeast, on 29th.

DATES OF—Auroras, 0; dense fog, 0; hail, 0; sleet, 0; halos: solar, 5, 6, 13, 15, 16, 21, 30; lunar, 11, 15. (Frosts not recorded.)

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, January, 1916.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	48	35	42	0.46	Cloudy	0
2	46	27	36	0	Cloudy	29
3	30	23	26	0	Partly cloudy	38
4	43	25	34	0	Cloudy	0
5	49	8	28	0.02	Cloudy	0
6	19	8	14	0	Partly cloudy	57
7	23	10	16	0	Clear	87
8	32	8	20	0	Partly cloudy	83
9	38	26	32	0.01	Cloudy	16
10	42	22	32	0.05	Cloudy	0
11	24	18	21	0.04	Cloudy	11
12	32	24	28	0.83	Cloudy	0
13	30	1	16	0.04	Cloudy	35
14	16	−1	8	0	Clear	100
15	22	8	15	0.03	Cloudy	6
16	21	−1	10	0.02	Cloudy	52
17	12	−2	5	0.01	Cloudy	60
18	13	7	10	0.03	Cloudy	57
19	21	9	15	0.01	Partly cloudy	60
20	36	20	28	0.08	Cloudy	0
21	57	36	46	0.40	Partly cloudy	46
22	50	30	40	0.01	Clear	82
23	39	26	32	0	Cloudy	33
24	50	31	40	0	Clear	100
25	51	40	46	0	Cloudy	39
26	52	43	48	0.04	Cloudy	5
27	61	35	48	0.10	Cloudy	15
28	35	23	29	0	Cloudy	5
29	33	24	28	0.06	Cloudy	0
30	35	33	34	0.78	Cloudy	0
31	34	19	26	0.09	Cloudy	0

Mean highest temperature	35.3
Mean lowest temperature	19.8
Mean temperature for month	27.6
Total precipitation for month	3.11

WEATHER

Number days clear	4
Partly cloudy	5
Cloudy	22
With 0.01 or more of precipitation	19

SUNSHINE

Number hours sunshine	95.6
Possible hours sunshine	292.5
Percentage of possible	33

This month since 1864.		
Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	22.3	0.94
1865	21.1	0.65
1866	21.2	2.03
1867	17.6	1.68
1868	19.0	1.47
1869	29.4	0.87
1870	25.4	1.93
1871	24.8	3.95
1872	21.6	0.42
1873	15.9	2.98
1874	27.7	3.53
1875	12.9	1.81
1876	30.2	1.63
1877	18.1	1.33
1878	29.1	1.12
1879	19.2	0.49
1880	37.1	2.67
1881	17.0	2.27
1882	24.9	1.47
1883	14.4	1.53
1884	15.5	1.23
1885	15.3	2.70
1886	18.8	2.66
1887	18.2	3.25
1888	15.4	2.18
1889	28.0	1.53
1890	31.5	2.31
1891	26.7	0.82
1892	19.2	0.96
1893	14.8	1.78
1894	26.9	1.37
1895	17.5	1.04
1896	24.6	0.79
1897	22.3	4.17
1898	24.9	3.07
1899	21.7	2.03
1900	25.6	1.17
1901	22.2	1.51
1902	20.5	0.43
1903	20.7	1.20
1904	14.4	2.82
1905	18.2	1.07
1906	31.8	1.99
1907	23.2	3.97
1908	23.8	1.89
1909	26.6	2.16
1910	23.4	2.52
1911	25.2	1.43
1912	9.2	0.80
1913	26.2	3.10
1914	27.0	2.98
1915	20.4	1.54
1916	27.6	3.11

BAROMETER—Mean, 30.11 inches; highest, 30.64 inches, on 8th; lowest, 29.39 inches, on 5th.

TEMPERATURE—Highest, 61°, on 27th; lowest, −2°, on 17th; greatest daily range, 41°, on 5th; least daily range, 2°, on 30th; normal for month, 22.7°; excess or deficiency this month, +4.9°; accumulated excess or deficiency since January 1st, +150°; average daily, same period, +4.9°; highest in 31 years, 63°; lowest, −26°.

PRECIPITATION (in inches)—Total amount, 3.11; normal, 2.09; excess or deficiency this month, +1.02; since January 1st, +1.02; greatest amount in any 24 hour period, 0.86, on 11th and 12th; total snowfall, 3.6 in.

WIND—Prevailing direction, south; total movement, 7,055 miles; average hourly velocity, 9.5 miles; maximum velocity, 31, from the west, on 5th.

DATES OF—Auroras, 0; dense fog, 0; hail, 0; sleet, 0; thunderstorms, 0; halos: solar, 8, 17, 19; lunar, 25. (Frosts not recorded.)

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, February, 1916.

Date.	Temperature. Highest.	Temperature. Lowest.	Temperature. Mean.	Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
1	19	10	14	0.01	Cloudy	38
2	15	9	12	0.01	Cloudy	2
3	18	7	12	0.03	Cloudy	59
4	23	9	16	0.03	Cloudy	52
5	33	23	28	0.11	Cloudy	12
6	27	16	21	0.03	Cloudy	2
7	16	0	8	0	Clear	99
8	20	2	11	0.05	Cloudy	0
9	23	13	18	0.01	Cloudy	17
10	24	13	18	0.02	Cloudy	48
11	21	15	18	0.11	Cloudy	7
12	23	10	16	0.02	Cloudy	38
13	19	−5	7	0	Clear	100
14	20	−14	3	0	Clear	100
15	31	17	24	0	Cloudy	34
16	39	17	28	0	Cloudy	26
17	43	25	34	0.03	Partly cloudy	62
18	34	8	21	0.10	Partly cloudy	65
19	29	8	18	0	Cloudy	14
20	31	6	18	0	Cloudy	7
21	28	−1	14	0	Clear	100
22	43	22	32	0.06	Cloudy	69
23	36	24	30	0.01	Partly cloudy	59
24	34	21	28	0	Partly cloudy	69
25	32	25	28	0	Cloudy	9
26	26	19	22	0.02	Cloudy	41
27	24	15	20	0.01	Cloudy	61
28	23	6	14	0.01	Cloudy	44
29	30	14	22	0.02	Partly cloudy	73
30						
31						

Mean highest temperature	27.0
Mean lowest temperature	11.5
Mean temperature for month	19.2
Total precipitation for month	0.69

WEATHER

Number days clear	4
Partly cloudy	5
Cloudy	20
With 0.01 or more of precipitation	19

SUNSHINE

Number hours sunshine	139.1
Possible hours sunshine	306.4
Percentage of possible	45

This month since 1864.

Year.	Mean temperature.	Total precipitation.
1863		
1864	27.3	0.27
1865	27.6	1.76
1866	22.7	2.28
1867	30.9	3.23
1863	18.7	1.28
1869	26.7	2.95
1870	24.2	1.20
1871	25.6	1.73
1872	21.3	0.46
1873	19.1	0.77
1874	25.5	1.55
1875	8.0	2.20
1876	27.4	3.04
1877	32.3	0.00
1878	28.1	2.74
1879	20.4	1.43
1880	29.2	1.62
1881	21.6	3.77
1882	35.1	2.28
1883	19.8	4.50
1884	23.4	3.69
1885	8.9	0.73
1886	22.3	1.35
1887	24.3	5.71
1888	22.0	1.70
1889	18.3	1.17
1890	31.5	1.79
1891	26.7	2.20
1892	27.3	1.93
1893	21.3	1.83
1894	21.2	0.53
1895	16.4	0.12
1896	24.3	1.51
1897	26.4	0.67
1898	23.8	1.82
1899	16.8	1.51
1900	17.4	3.44
1901	12.8	1.83
1902	18.6	0.44
1903	20.6	1.58
1904	12.0	3.30
1905	15.8	1.25
1906	23 6	1.12
1907	19.2	0.25
1908	21.6	3.19
1909	28.4	2.36
1910	21.9	2.65
1911	27.6	1.77
1912	15.8	2.04
1913	20.0	1.65
1914	12.7	0.79
1915	29.4	2.10
1916	19.2	0.69

BAROMETER—Mean, 30.12 inches; highest, 30.74 inches, on 14th; lowest, 29.53 inches, on 26th.

TEMPERATURE—Highest, 43°, on 22nd; lowest, −14°, on 14th; greatest daily range, 34°, on 14th; least daily range, 6°, on 11th; normal for month, 21.6°; excess or deficiency this month, −2.4°; accumulated excess or deficiency since January 1st, +77°; average daily, same period, +1.3°; highest in 31 years, 62°; lowest, −25°.

PRECIPITATION (in inches)—Total amount, 0.69; normal, 2.09; excess or deficiency this month, −1.40; since January 1st, −0.38; greatest amount in any 24 hour period, 0.13, on 4th and 5th; total snowfall, 9.1 inches.

WIND—Prevailing direction, west; total movement, 5,116 miles; average hourly velocity, 7.4 miles; maximum velocity, 26, from the northwest, on 26th.

DATES OF—Auroras, 20; dense fog, 0; hail, 0; sleet, 0; thunderstorms, 0; halos: solar, 4, 15, 17, 28; lunar, 10, 14, 16. (Frosts not recorded.)

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, March, 1916.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	22	12	17	0.04	Cloudy	0
2	25	3	14	0.05	Cloudy	84
3	24	2	13	0.01	Cloudy	61
4	29	5	17	0	Partly cloudy	89
5	28	8	18	0.08	Partly cloudy	96
6	42	19	30	0.17	Cloudy	0
7	35	23	29	0.14	Partly cloudy	62
8	23	14	18	0.02	Cloudy	58
9	35	6	20	0.32	Cloudy	39
10	28	12	20	0	Clear	100
11	34	8	21	0.03	Partly cloudy	82
12	40	28	34	0.02	Cloudy	16
13	38	28	33	0	Partly cloudy	81
14	28	14	21	0.02	Cloudy	1
15	22	9	16	0	Cloudy	82
16	30	7	18	0	Cloudy	62
17	21	3	12	0	Clear	100
18	30	12	21	0	Cloudy	8
19	32	16	24	0	Clear	100
20	32	17	24	0.09	Cloudy	6
21	42	29	36	0.25	Cloudy	52
22	32	5	18	0.40	Cloudy	66
23	31	−4	14	0	Clear	100
24	45	19	32	0.01	Cloudy	69
25	67	36	52	0	Partly cloudy	78
26	46	36	41	0.53	Cloudy	0
27	36	33	34	0.88	Cloudy	0
28	38	33	36	0.03	Cloudy	0
29	49	34	42	0	Partly cloudy	73
30	58	31	44	0	Partly cloudy	68
31	60	28	44	0	Partly cloudy	42

Mean highest temperature	35.5
Mean lowest temperature	17.0
Mean temperature for month	26.2
Total precipitation for month	3.09

WEATHER

Number days clear	4
Partly cloudy	9
Cloudy	18
With 0.01 or more of precipitation	18

SUNSHINE

Number hours sunshine	199.7
Possible hours sunshine	370.5
Percentage of possible	54

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863		
1864	31.7	2.26
1865	37.0	2.79
1866	29.1	3.39
1867	29.7	0.68
1868	37.8	4.65
1869	27.6	1.65
1870	30.3	3.01
1871	38.2	3.91
1872	24.8	2.04
1873	28.3	1.73
1874	32.3	1.79
1875	26.2	1.02
1876	30.6	4.84
1877	24.5	5.60
1878	40.9	3.12
1879	33.2	1.57
1880	35.5	1.70
1881	30.3	2.66
1882	36.0	3.58
1883	24.9	0.71
1884	29.9	3.67
1885	21.3	0.58
1886	31.3	2.63
1887	28.3	1.78
1888	27.0	1.88
1889	37.6	1.22
1890	28.2	1.54
1891	29.3	2.41
1892	29.9	1.31
1893	28.2	2.82
1894	40.1	1.25
1895	27.2	0.27
1896	28.7	1.31
1897	33.0	2.08
1898	37.0	3.59
1899	26.3	3.30
1900	23.6	1.88
1901	31.1	2.94
1902	38.0	3.16
1903	41.0	1.25
1904	30.2	3.45
1905	35.4	3.15
1906	26.2	1.86
1907	38.6	2.84
1908	34.8	2.19
1909	29.9	0.90
1910	44.0	0.40
1911	32.7	1.21
1912	22.4	1.92
1913	31.0	3.76
1914	31.1	1.52
1915	30.1	0.78
1916	26.2	3.09

BAROMETER—Mean, 29.97 inches; highest, 30.49 inches, on 17th; lowest, 29.10 inches, on 6th.

TEMPERATURE—Highest, 67°, on 25th; lowest, −4°, on 23rd; greatest daily range, 35°, on 23d; least daily range, 3°, on 27th; normal for month, 32.3°; excess or deficiency this month, −6.1°; accumulated excess or deficiency since January 1st, −110°; average daily, same period, −1.2°; highest in 31 years, 82°, lowest, −12°.

PRECIPITATION (in inches)—Total amount, 3.09; normal, 2.26; excess or deficiency this month, +0.83; since January 1st, +0.45; greatest amount in any 24 hour period, 1.33, on 26th and 27th; total snowfall, 19.3 inches.

WIND—Prevailing direction, northeast; total movement, 5,908 miles; average hourly velocity, 7.9 miles; maximum velocity, 31, from the northwest, on 9th.

DATES OF—Auroras, 8; dense fog, 26, 29, 30, 31; hail, 0; sleet, 24; thunderstorms, 6, 9; halos: solar, 2, 3, 4, 5, 13, 16, 21, 31. (Frosts not recorded.)

DEWEY A. SEELEY.
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, April, 1916.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1........	50	32	41	0.31	Partly cloudy...	32
2........	52	28	40	0	Clear..........	99
3........	52	29	40	0	Clear..........	100
4........	51	34	42	0	Partly cloudy...	71
5........	51	29	40	0.03	Partly cloudy...	78
6........	42	27	34	0.01	Partly cloudy...	75
7........	44	23	34	0	Partly cloudy...	80
8........	37	27	32	0	Cloudy.........	11
9........	46	27	36	0	Clear..........	100
10........	55	24	40	0	Clear..........	98
11........	63	39	51	0.10	Partly cloudy...	61
12........	53	38	46	0	Cloudy.........	16
13........	75	43	59	0.47	Cloudy.........	41
14........	54	35	44	0.01	Partly cloudy...	50
15........	61	30	46	0	Clear..........	84
16........	70	42	56	0.13	Partly cloudy...	37
17........	52	38	45	0	Cloudy.........	17
18........	64	35	50	0	Partly cloudy...	100
19........	54	42	48	0.44	Cloudy.........	15
20........	78	44	61	0.05	Cloudy.........	57
21........	57	43	50	0.03	Cloudy.........	13
22........	43	38	40	0.10	Cloudy.........	0
23........	47	38	42	0.01	Cloudy.........	0
24........	53	39	46	0.06	Cloudy.........	22
25........	48	41	44	0.04	Cloudy.........	10
26........	53	41	47	0.02	Cloudy.........	13
27........	60	40	50	0	Clear..........	81
28........	66	35	50	0	Clear..........	97
29........	70	43	56	0	Clear..........	96
30........	70	46	58	0.10	Cloudy.........	39
31........	....	....	....	....	....	....

Mean highest temperature	55.7
Mean lowest temperature	35.7
Mean temperature for month	45.7
Total precipitation for month	1.91

WEATHER

Number days clear	8
Partly cloudy	9
Cloudy	13
With 0.01 or more of precipitation	16

SUNSHINE

Number hours sunshine	212.9
Possible hours sunshine	402.5
Percentage of possible	53

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	45.9	3.80
1865	47.4	2.32
1866	48.9	1.40
1867	48.2	2.19
1868	43.7	1.83
1869	45.7	3.42
1870	50.4	2.02
1871	49.8	2.97
1872	47.4	1.26
1873	43.2	3.88
1874	36.9	1.67
1875	41.1	0.61
1876	44.2	2.08
1877	46.2	4.14
1878	50.6	3.76
1879	44.8	1.25
1880	45.9	7.06
1881	45.6	1.73
1882	44.7	1.88
1883	43.5	1.90
1884	43.7	1.95
1885	43.6	2.47
1886	50.2	1.99
1887	45.4	0.90
1888	44.0	1.15
1889	46.6	2.02
1890	47.2	3.20
1891	47.4	1.74
1892	44.5	2.04
1893	43.5	4.81
1894	48.4	2.76
1895	48.6	0.67
1896	52.6	2.77
1897	44.6	2.74
1898	43.6	2.12
1899	49.8	1.23
1900	47.4	2.00
1901	46.4	2.16
1902	44.6	1.70
1903	43.0	4.40
1904	39.4	0.50
1905	44.6	1.49
1906	46.6	2.43
1907	37.8	2.81
1908	44.6	2.15
1909	42.8	5.96
1910	49.2	2.48
1911	44.3	2.11
1912	45.6	3.12
1913	45.9	3.10
1914	44.7	2.90
1915	51.6	1.00
1916	45.7	1.91

BAROMETER—Mean, 29.95 inches; highest, 30.26 inches, on 6th; lowest, 29.52 inches, on 21st.

TEMPERATURE—Highest, 78°, on 20th; lowest, 23°, on 7th; greatest daily range, 34°, on 20th; least daily range, 5°, on 22d; normal for month, 45.6°; excess or deficiency this month, +0.1°; accumulated excess or deficiency since January 1st, −111°; average daily, same period, −0.9°; highest in 31 years, 86°; lowest, 10°.

PRECIPITATION (in inches)—Total amount, 1.91; normal, 2.54; excess or deficiency this month, −0.63; since January 1st, −0.18; greatest amount in any 24 hour period, 0.48, on 13th and 14th; total snowfall, 0.2 inches.

WIND—Prevailing direction, northwest; total movement, 5,783 miles; average hourly velocity, 8.0 miles; maximum velocity, 30, from the northwest, on 14th.

DATES OF—Auroras, 27, 28; dense fog, 0; sleet, 0; thunderstorms, 11, 12, 13,14, 16, 19; halos: solar, 3, 7, 13, 15, 18; lunar, 18; Frost: killing, 15; (Frosts recorded after April 15th.)

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, May, 1916.

Date.	Temperature.			Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	59	40	50	0.26	Cloudy	0
2	52	37	44	0	Cloudy	12
3	54	41	48	0.28	Cloudy	4
4	63	37	50	0	Partly cloudy	83
5	71	48	60	0	Partly cloudy	94
6	69	48	58	0.59	Cloudy	5
7	72	49	60	0	Clear	100
8	67	53	60	0.03	Clear	85
9	65	40	52	0	Clear	100
10	74	50	62	0.50	Cloudy	28
11	61	43	52	0	Clear	100
12	59	36	48	0	Cloudy	71
13	64	41	52	0.12	Cloudy	77
14	61	46	54	0.81	Cloudy	25
15	72	59	66	1.03	Cloudy	74
16	60	42	51	0.01	Cloudy	39
17	46	40	43	0	Cloudy	19
18	55	39	47	0.01	Cloudy	61
19	57	40	48	0.03	Partly cloudy	68
20	64	35	50	0	Partly cloudy	100
21	60	42	51	0.01	Cloudy	54
22	66	52	59	0.34	Cloudy	11
23	79	52	66	0	Clear	96
24	80	50	65	0	Partly cloudy	93
25	81	58	70	0	Partly cloudy	100
26	80	57	68	0	Clear	99
27	83	60	72	0.06	Partly cloudy	57
28	80	54	67	0	Partly cloudy	99
29	74	57	66	1.04	Cloudy	25
30	72	49	60	0.01	Partly cloudy	92
31	67	44	56	0	Clear	100

Mean highest temperature	66.7
Mean lowest temperature	46.4
Mean temperature for month	56.6
Total precipitation for month	5.13

WEATHER

Number days clear	7
Partly cloudy	9
Cloudy	15
With 0.01 or more of precipitation	16

SUNSHINE

Number hours sunshine	289.7
Possible hours sunshine	454.7
Percentage of possible	64

This month since 1864.		
Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	60.2	2.87
1865	57.6	1.77
1866	55.0	3.48
1867	61.1	3.80
1868	59.1	2.80
1869	56.0	2.05
1870	64.3	1.16
1871	61.4	1.97
1872	58.5	3.72
1873	56.9	3.05
1874	59.6	1.77
1875	60.8	4.46
1876	58.0	4.13
1877	58.2	2.23
1878	54.6	3.44
1879	58.8	2.45
1880	64.3	5.59
1881	65.2	2.11
1882	52.7	4.04
1883	52.8	5.66
1884	56.9	3.95
1885	55.8	2.30
1886	58.1	2.67
1887	64.3	2.42
1888	53.7	3.66
1889	57.4	3.61
1890	53.7	4.98
1891	55.7	1.63
1892	54.5	5.92
1893	54.4	2.86
1894	56.9	4.83
1895	61.8	2.06
1896	66.5	3.14
1897	55.8	3.29
1898	56.5	2.15
1899	58.8	3.59
1900	58.8	4.17
1901	55.2	2.42
1902	58.4	4.92
1903	59.5	2.63
1904	57.4	2.40
1905	56.7	5.17
1906	56.6	3.05
1907	51.2	2.22
1908	59.6	5.59
1909	55.8	2.44
1910	51.5	4.13
1911	63.5	2.67
1912	57.6	6.57
1913	56.2	2.22
1914	58.6	4.66
1915	51.5	2.74
1916	56.6	5.12

BAROMETER—Mean, 29.90 inches; highest, 30.36 inches, on 13th; lowest, 29.38 inches, on 10th.

TEMPERATURE—Highest, 83°, on 27th; lowest, 35°, on 20th; greatest daily range, 30°, on 24th; least daily range, 6°, on 17th; normal for month, 57.1°; excess or deficiency this month, −0.5°; accumulated excess or deficiency since January 1st, −125°; average daily, same period, −0.8°; highest in 31 years, 95°; lowest, 17°.

PRECIPITATION (in inches)—Total amount, 5.13; normal, 3.58; excess or deficiency this month, +1.55; since January 1st, +1.37; greatest amount in any 24 hour period, 1.80, on 14th and 15th; total snowfall, 0.0 inches.

WIND—Prevailing direction, southwest; total movement, 5,132 miles; average hourly velocity, 6.9 miles; maximum velocity, 28, from the northwest, on 11th.

DATES OF—Auroras, 0; dense fog, 0; sleet, 0; thunderstorms, 6, 8, 10, 14, 15, 27, 29; halos: solar, 12, 13, 14, 21, 24, 25, 28; lunar, 9, 15; frost: killing, 0; heavy, 0; light, 4, 19, 20.

DEWEY A. SEELEY,
Local Forecaster.

Monthly Meteorological Summary, Lansing, Michigan, June, 1916.

Date.	Temperature. Highest.	Temperature. Lowest.	Temperature. Mean.	Precipitation, in inches.	Character of day.	Percentage of possible sunshine.
1	73	43	58	0	Partly cloudy	80
2	74	55	64	0.13	Partly cloudy	69
3	68	49	58	0	Clear	84
4	73	49	61	0.01	Partly cloudy	61
5	71	48	60	0	Partly cloudy	96
6	69	50	60	0.14	Cloudy	57
7	58	51	54	0.61	Cloudy	3
8	61	52	56	0.29	Cloudy	18
9	63	53	58	0.20	Cloudy	29
10	67	49	58	0	Cloudy	53
11	74	50	62	0	Partly cloudy	73
12	76	50	63	0	Partly cloudy	100
13	81	52	66	0	Clear	89
14	69	57	63	0.38	Cloudy	24
15	76	55	66	0.25	Partly cloudy	77
16	69	54	62	0.50	Cloudy	66
17	66	54	60	0.30	Partly cloudy	68
18	70	52	61	0.12	Partly cloudy	63
19	67	44	56	0	Partly cloudy	60
20	68	41	54	0.01	Partly cloudy	83
21	63	49	56	0.13	Cloudy	61
22	74	49	62	0	Partly cloudy	88
23	78	53	66	0.43	Partly cloudy	62
24	75	61	68	0.06	Partly cloudy	73
25	76	54	65	0	Clear	100
26	80	53	66	0.25	Cloudy	61
27	68	51	60	0	Partly cloudy	50
28	77	48	62	0	Clear	100
29	79	56	68	0.43	Cloudy	82
30	78	58	68	1.15	Partly cloudy	60
31	....	....	....	....	....	....

Mean highest temperature	71.4
Mean lowest temperature	51.3
Mean temperature for month	61.4
Total precipitation for month	5.39

WEATHER

Number days clear	4
Partly cloudy	16
Cloudy	10
With 0.01 or more of precipitation	18

SUNSHINE

Number hours sunshine	304.6
Possible hours sunshine	459.4
Percentage of possible	66

This month since 1864. Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	67.6	3.88
1865	70.8	3.55
1866	66.6	5.37
1867	71.6	2.83
1868	68.5	3.55
1869	64.4	4.40
1870	70.9	7.27
1871	68.2	2.93
1872	71.8	3.45
1873	70.6	2.96
1874	70.6	5.07
1875	66.6	1.84
1876	68.1	4.34
1877	65.9	3.53
1878	64.1	3.15
1879	66.0	2.87
1880	67.6	5.04
1881	64.3	4.37
1882	66.5	15.57
1883	65.9	1.35
1884	68.9	2.83
1885	64.7	6.01
1886	65.7	1.92
1887	68.5	2.47
1888	67.9	2.51
1889	62.8	3.42
1890	70.3	3.92
1891	67.4	2.55
1892	67.7	4.33
1893	66.6	4.85
1894	71.4	1.30
1895	71.4	1.01
1896	69.9	2.60
1897	64.2	2.57
1898	67.6	4.91
1899	68.2	1.15
1900	65.2	2.57
1901	68.0	3.57
1902	61.8	7.28
1903	....	6.28
1904	65.6	2.49
1905	66.2	7.47
1906	67.1	4.61
1907	65.0	2.37
1908	70.0	1.23
1909	66.7	2.86
1910	64.9	1.95
1911	68.0	3.77
1912	63.1	0.97
1913	67.6	1.01
1914	66.0	4.11
1915	61.0	3.96
1916	61.4	5.39

BAROMETER—Mean, 29.87 inches; highest, 30.34 inches, on 22d; lowest, 29.39 inches, on 7th.

TEMPERATURE—Highest, 81°, on 13th; lowest, 41°, on 20th; greatest daily range, 30° on 1st; least daily range, 7°, on 7th; normal for month, 61.4°; excess or deficiency this month, −5.8°; accumulated excess or deficiency since January 1st, −299°; average daily, same period, −1.1°; highest in 31 years, 99°; lowest, 34°.

PRECIPITATION (in inches)—Total amount, 5.39; normal, 3.40; excess or deficiency this month, +1.99; since January 1st, +3.36; greatest amount in any 24 hour period, 1.58, on 29th and 30th; total snowfall, 0.0 inch.

WIND—Prevailing direction, southwest; total movement, 3,818 miles; average hourly velocity, 5.3 miles; maximum velocity, 21, from the east on 6th.

DATES OF—Auroras, 0; dense fog, 0; hail, 0; sleet, 0; thunderstorms, 2, 4, 8, 14, 15, 16, 17, 23, 26, 29; halos: solar, 6, 15, 29; lunar, 14, frost: killing, 0; heavy, 0; light, 0.

DEWEY A. SEELEY,
Local Forecaster.

TWENTY-NINTH ANNUAL REPORT

OF THE

EXPERIMENT STATION

OF THE

Michigan Agricultural College

UNDER THE HATCH AND ADAMS ACTS

FOR THE

YEAR ENDING JUNE 30, 1916

For members and organization of the State Board of Agriculture in charge of the Station and list of officers, see page 15 of this volume.

REPORT OF SECRETARY AND TREASURER.

The following shows the receipts and disbursements of the Experiment Station for the year ending June 30, 1916:

		Dr.	Cr.
July 1, 1915.	To balance	$2,139 81	
Aug. 11, 1915.	received from U. S. Treasury	7,500 00	
Oct. 13, 1915.	received from U. S. Treasury	7,500 00	
Jan. 15, 1916.	received from U. S. Treasury	7,500 00	
April 6, 1916.	received from U. S. Treasury	7,500 00	
June 30, 1916.	license fees, 292 brands commercial fertilizers	5,840 00	
	license fees, 435 brands commercial feeding stuffs	8,700 00	
	farm and miscellaneous receipts	626 82	
	from State appropriation, South Haven Experiment Station	2,000 00	
	from State appropriation, U. P. Experiment Station	9,850 00	
	from South Haven Experiment Station, receipts	233 02	
	from U. P. Experiment Station, receipts	3,712 10	
	apportioned from 1-5 mill fund	15,555 00	
	By disbursements as per vouchers filed in the office of the State Auditor General	....	$71,672 44
	balance on hand	....	6,984 31
	Total	$78,656 75	$78,656 75

Fifty thousand regular bulletins No. 275; seven thousand special bulletions No. 74; seven thousand special bulletins No. 75; fifteen thousand special bulletins No. 76; twelve thousand special bulletins No. 77; fifteen thousand special bulletins No. 78; eight thousand special bulletins No. 79; fifty thousand circulars No. 28; twenty-two thousand five hundred circulars No. 29; five thousand circulars No. 30; five thousand technical bulletins No. 25; five thousand technical bulletins No. 26; five thousand technical bulletins No. 27; and one thousand press bulletins No. 42; one thousand press bulletins No. 43; seven hundred fifty press bulletins No. 44; seven hundred fifty press bulletins No. 45; seven hundred fifty press bulletins No. 46; seven hundred fifty press bulletins No. 47; one thousand press bulletins No. 48; and one thousand press bulletins No. 49 have been issued by the Experiment Station during the fiscal year.

DISBURSEMENTS ON ACCOUNT OF U. S. APPROPRIATIONS.

	Hatch fund.	Adams fund.
Salaries:		
Director and other administrative officers	$2,020 00	....
Scientific staff	2,616 00	$867 40
Assistants to scientific staff	4,840 90	9,226 40
Labor:		
Annual and monthly employees	655 57	800 00
Balance by week, day and hour as needed	793 54	1,264 38
Publications:		
Other expenses (copper half-tones)	77 27	....
Postage and stationery:		
Postage	35 86	1 96
Stationery	50 81	3 73
Telegraph and telephone	5 24	....

DISBURSEMENTS ON ACCOUNT OF U. S. APPROPRIATIONS—*Continued.*

	Hatch fund.	Adams fund.
Freight and express	$44 70	$0 69
Heat, light, water and power:		
Heat	200 15	
Chemicals and laboratory supplies:		
Chemicals	246 39	211 80
Other supplies	78 83	481 67
Seeds, plants and sundry supplies:		
Agricultural	226 37	4 31
Horticultural	581 09	
Botanical	124 93	38 24
Entomological	18 03	
Bacteriological	4 00	22 76
Chemical	25 78	14 94
Soils	48 15	11 15
Fertilizers	117 70	
Feeding stuffs	57 75	299 76
Library:		
One copy American Journal of Physiology	10 00	
One set catalogue cards	89 64	
One year subscription Chemisches Centralblatt	20 00	
One year subscription sylloge Fungorium	25 00	
One year subscription Centralblatt	5 50	
Eight parts Insecta	24 00	
One set Zeitschrift phys. Chemie	41 80	
One copy Physiology		5 03
One copy Monogramia Uredinearium		7 60
One copy Jl. of Ind. and Eng. Chem	12 60	
One copy Jl. of Soc. of Chem. Industry	9 50	
One copy Jl. of Royal Microscope Society	9 00	
One copy Jl. of Economy Biology	5 25	
One copy Jl. of Exp. Medicine	9 30	
One set Biochemische Zeitschrift	6 72	
One copy Chem. Pathology		3 07
One copy Ernahrungsphysiologisches		3 60
Other purchases	228 17	8 37
Tools, machinery and appliances:		
New purchases	459 60	59 25
Repairs	39 01	

Items of principal purchase:	Hatch.	Adams.
One 22 x 31 Farquhar Separator	$315 68	
Two galv. pans	79 66	
One No. 6 brass pump	11 00	
One folding tower sprayer	9 48	
One pressure regulator, compl	10 00	
One No. 806 scale		$11 37
One pressure cooker		18 75

	Hatch fund.	Adams fund.
Furniture and fixtures:		
One Remington typewriter	70 00	
One typewriter	35 00	
One G. O. Dull office desk	17 00	
One oak case	50 67	
One Smith-Premier typewriter	70 00	
One office desk	28 00	
Three cabinets and guides		13 74
One office desk	12 00	
Two desk chairs	14 06	
Other purchases	25 29	3 73
Scientific apparatus and specimens:		
Four chemical thermometers	9 97	
Two chemical thermometers	6 38	
Thirty freezing point tubes	23 10	
Six electrolytic cells		43 10
One pressure cooker		14 25
One animal board No. 5155		35 00
One distilling apparatus		75 00
One chemical microscope		90 58
One milk sediment tester		10 10
One condenser		23 12
Five 10 in. animal jars		19 00
Two Beckman thermometers		24 00

DISBURSEMENTS ON ACCOUNT OF U. S. APPROPRIATIONS.—*Concluded.*

	Hatch fund.	Adams fund.
Scientific apparatus and specimens.—*Con:*		
Two dozen Ammonia Abs. tubes		$37 80
One Beckman thermometer		28 00
One calorimeter	$18 00	
Other purchases	5 00	193 11
Live stock:		
Cattle		10 00
Swine		90 90
Small experimental animals		182 98
Traveling expenses:		
In supervision of station work	248 61	
In connection with investigations under Adams act		30 59
For other purposes connected with station work	464 93	
Contingent expenses:		
One year dues, 1915-1916, Association of American Colleges and Experiment Stations	20 00	
Buildings and land:		
New buildings	17 81	738 89
Total	$15,000 00	$15,000 00

DISBURSEMENTS OF EXPERIMENT STATION MONEYS—OTHER THAN RECEIVED FROM U. S. TREASURER.

Salaries	$19,032 46
Labor	9,186 51
Publications	18 69
Postage and stationery	446 13
Freight and express	520 05
Heat, light, water and power	18 25
Chemicals and laboratory supplies	664 59
Seeds, plants, and sundry supplies	1,848 27
Fertilizers	7 50
Feeding stuffs	2,847 75
Library	56 80
Tools, machinery and appliances	895 73
Furniture and fixtures	166 99
Scientific apparatus and specimens	291 88
Live stock	1,960 12
Traveling expenses	3,055 99
Contingent expenses	5 00
Buildings and land	649 73
Balance	6,984 31
Total	$48,656 75

REPORT OF THE DIRECTOR OF THE EXPERIMENT STATION.

To President F. S. Kedzie:

The details of the work of this Experiment Station are quite fully covered in the reports of the various departments and in the official publications of the year. No changes have taken place in the personnel of the Station Council except in the case of the Horticultural department, where Prof. C. P. Halligan took charge in a very satisfactory way during the year while Vice-Director H. J. Eustace was away on a year's leave of absence.

The lines of work pursued by the various departments under Adams were largely a continuation of work in progress except in a few instances where projects were completed and superseded by others. The organization of Extension work in the State and the establishment of more than a score of county agents has brought to the Experiment Station many new demands for assistance, which have been taken care of as far as possible from Hatch and State funds. We were fortunate this year in receiving larger appropriations from the State, generously granted by the Board of Agriculture.

For this year the various Experiment Station funds were apportioned and used as follows, viz.: Hatch fund, salaries $9,476.90, working equipment and operating expenses $5,523.10; Adams fund, salaries $10,093.80, working equipment and operating expenses $4,906.20. The total state funds expended during the year amounted to $27,881.53, including $15,555.00 appropriated directly by the State Board of Agriculture, the balance of $12,326.53 being derived from license fees and sundry receipts. In addition to those sums $9,850.00 was appropriated from current funds of the institution for the maintenance and development of the Upper Peninsula Station at Chatham. The total expenditures of the Experiment Station for the year, therefore, amounted to $71,672.44. These funds do not represent the total support given the Experiment Station as the College, with some few exceptions, provides buildings for officers and laboratories with both light and heat.

During the year special equipment was procured through the use of state funds for classifying the bulletin mailing list, which has grown to enormous proportions and which could not serve the public satisfactorily in an economical way. Station publications have been classified into ten groups as follows, viz.: 1. ANIMAL HUSBANDRY—Beef Cattle, Sheep, Hogs and Horses; 2. DAIRY HUSBANDRY—Dairy Cattle, Milk, Butter and Cheese; 3. FIELD CROPS—Grains, Forage and Root Crops; 4. HORTICULTURE—Fruits, Small Fruits and Vegetables; 5. SOILS; 6. POULTRY; 7. BEES; 8. FORESTRY; 9. PLANT DISEASES; 10. ANIMAL DISEASES. Before placing a name on the list the individual is required to indicate which group or groups are desired. In addition to subject classification, the following regional and special grouping has been made:

Michigan (lower peninsula)	36,000
Michigan (upper peninsula)	950
Other states	1,800
Libraries, schools, etc.	978
Firms	200
Foreign	191
Extension workers	100
Press (Michigan)	543
Press (other states)	176
Official	2,800
Total	43,738

Owing to a lack of funds for publicity during the previous year some manuscripts had to be carried over, resulting in a long list of bulletins for the year ending June 30th. The list of twenty publications for the year include the following, viz.:

Popular—
- 275—Fertilizer Analyses.

Circular—
- 28—The Bean-Maggot in 1915.
- 29—Infectious Abortion in Cattle.
- 30—Cucumber Growing.

Special—
- 74—Analyses of Some Materials Sold as Insecticides and Fungicides.
- 75—Durability of Concrete Drain Tile.
- 76—Transferring Bees.
- 77—The Septoria Leaf Spot Disease of Celery or Celery Blight (English and Dutch Editions.)
- 78—Christmas Tree Plantations.
- 79—Michigan's Shifting Sands—Their Control and Better Utilization.

Technical—
- 20—Experiments on the Control of the Root-Knot Nematode.
- 21—How Contact Insecticides Kill.
- 22—Effect of Temperature on some of the most Important Physical Processes in Soils.
- 23—A Simplified Apparatus for Measuring the Conductivity of Electrolytes.
- 24—The Freezing Point Method as a New Means of Measuring the Concentration of the Soil Solution Directly in the Soil.
- 25—Leaf Spot Disease of Tomato.
- 26—Soil Temperature.
- 27—The Freezing Point Method as a New Means of Determining the Nature of Acidity and Lime Requirements of Soils.

Press—
- 42—The Bean Situation in Michigan.
- 43—How to Cure and Store Seed Corn. Corn Selection for Exhibit Purposes.
- 44—The Seed Corn Situation.

45—Prevention of Celery "Blight."
46—Transferring Bees.
47—Durability of Concrete Drain Tile.
48—Recommendation for Spraying Grapes.
49—Sudan Grass.

In November, 1915, Popular Bulletin No. 267 "Michigan Weeds," by Dr. W. J. Beal, was revised by Dr. E. A. Bessey, and a reprint of 20,000 copies made.

On March 15, 1916, Mr. Burton W. Housholder succeeded Mr. R. G. Carr as Superintendent of the Upper Peninsula Station at Chatham. During the present season Mr. Housholder has made very satisfactory progress with the land clearing work, having put quite a large area under cultivation for the first time, and also rough burned and seeded about 200 acres of recently cut over land. The preparation of a larger crop producing area on the Station farm, is necessary for the development of the various phases of live stock production and investigation, the basic feature of the development of the agriculture of that region. Without an adequate crop producing area the maintenance of large herds for experimental purposes is too costly on account of the long distance feed stuffs must be transported by rail.

The building equipment is now complete except for the provision of a horse barn and implement shed, which would have been constructed during the present year had it not been for the stringency of funds caused by the disastrous fire loss of the College.

The Holstein herd now consists of nine cows, twelve heifers, and two bulls of choice breeding. Eight cows have been admitted to the A. R. O. on the basis of official seven-day tests. During the year five young bulls were sold at reasonable prices to become herd headers in the northern part of the State.

Other stock comprises 44 Durco Jersey hogs, and a flock of 252 sheep, including Rambouillets, Hampshires, and western range stocks. Flocks of Barred Plymouth Rocks and White Leghorn chickens are maintained. It is the plan now to undertake pedigreed horse breeding at an early date.

During this season the following crops were grown on the Station farm in addition to hay and pasture, viz.: 8 acres of barley, 7 acres of oats, 8 acres of oats and peas for hay and ensilage, 8 acres of field roots and 3 acres of potatoes. Experimental tests were continued with varieties of oats, wheat, barley, potatoes, alfalfa and soy beans.

In the near future it has been planned to issue a special bulletin, giving detailed data relating to various phases of agriculture in the Upper Peninsula which has been procured during the past two and three years.

Respectfully submitted,
R. S. SHAW,
Director of Experiment Station.

East Lansing, Mich., June 30, 1916.

REPORT OF BACTERIOLOGIST.

Dean R. S. Shaw:

Dear Sir—Projects under investigation in this laboratory have not changed materially during the past year. The personnel of the laboratory staff, however, has undergone change and its incompleteness has been reflected in the lack of progress in one of our projects a condition which bids fair to be remedied in the immediate future. We are carrying on research under five projects supported by the Adams fund as follows:

1a. The effect of diseases in the cow on the milk.
1b. The keeping qualities of butter.
2c. Soil solution and its rôle in the life of soil microbes.
3a. Swine epidemics.
3b. Bovine infectious abortion.

It is proper to state that in addition to the strictly original investigations of a more purely scientific nature in connection with the problems outlined above there are given consideration under the respective headings various subsidiary and related phases of a more immediately practical or applicable nature. These side lights on the main Adams fund projects are supported by the Hatch and State funds allotted to this department as is also certain unrelated experimental work as outlined below:

1. Animal diseases.
    a. Chicken diseases, with special reference to white diarrhea and roup.
    b. Occasional diseases that come to our notice.
2. Nodule-forming bacteria.
3. Various fermentations.
    a. Vinegar.
    b. Pickles.
    c. Milk.
    d. Stock foods, grains, silage, etc.
4. Dairy sanitation.
5. Rural water supplies.

The investigations supported by Hatch and State funds are conducted by the men having charge of the various Adams fund projects, except that Miss L. Z. Northrup, Assistant Bacteriologist, and Mr. W. L. Kulp, Instructor in Bacteriology have frequently responded to calls for assistance in connection with the unrelated examinations that are demanded of us.

Mr. L. H. Cooledge has continued in charge of Adams projects 1a and all related problems and investigations. I cannot speak too highly of his ability and versatility, of his industry and reliability. I have to ac knowledge my increasing indebtedness to him for his loyalty and support. His report follows:

One third of my time during the past year has been given to work of a popular nature.

Much time has been taken up by the examination of a large number of samples of milk which have been submitted to the laboratory for examination, and to correspondence with dairymen along the lines of dairy hygiene.

One third of my time has been given to technical research, (Adams). I have continued my studies on the effect of diseases in the cow on the milk with special reference to infectious abortion. Facts which have developed in the course of this work are embodied in the following papers and published articles:

Studies in Infectious Abortion in Cattle.
By Ward Giltner, E. T. Hallman and L. H. Cooledge.
Presented at the meeting of the American Veterinary Medical Association. Section on Sanitary Science and Police, Oakland California, Sept, 1915. Published in Journal of American Veterinary Medical Association, June, 1916.

The Pathogenic and Antigenic Properties of Bact. Abortus (Bang).
By Ward Giltner and L. H. Cooledge.
Presented at the May meeting of the American Association of Pathologists and Bacteriologists, Washington, D. C. Presented by Dr. Giltner.

The Agglutination Test as a Means of Studying the Presence of Bact. Abortus (Bang) in Milk.
By L. H. Cooledge. Presented at the Meeting of the Michigan Academy of Science. Published in the Journal of Agricultural Research, Vol. 5, No. 19.

Further Studies on the Presence and Significance of the Agglutinins for Bact. abortus (Bang) in Cows' Milk.
Presented at the Meeting of the Society of American Bacteriologists at Urbana, Ill., December, 1915. Abstracted in Journal of Bacteriology, Vol. I, No. 1, January, 1916.

Is Bact. abortus (Bang) Pathogenic for the Human?
By L. H. Cooledge.
Published in the Journal of Medical Research, Vol. XXXIV, No. 3.

The following summary of the work reported on in the above papers is given as an indication of progress:

A pure culture of *Bacterium abortus* introduced into the milk cistern of a cow's udder caused the appearance of agglutinins in the milk.

In every case in which Bact. abortus was found present in the milk by animal inoculation the agglutinins for this organism were also found, but this bacterium was not found in every case in which agglutinins were demonstrated. It is not known, however, whether the bacteria were not found because of their absence or because of their presence in such small numbers.

The agglutination test is of value in studying the presence of *Bact. abortus* in milk when it is desired to study a large number of samples.

If *Bact. abortus* is found to be pathogenic for humans, this test may be of value as another means of safeguarding certified and all unpasturized milk.

We have no conclusive evidence that *Bact. abortus* is pathogenic for human beings, but it is possible to cause antibodies for *Bact. abortus* to appear in the blood of adults by feeding a milk which is naturally infected with *Bact. abortus* and which contains the *Bact. abortus* antibodies.

Antibodies appearing as above apparently indicate a passive immunity due to the absorption in the large intestine of the antibodies present in the milk.

Mr. I. F. Huddleson has been working on the transmission of *Bact. abortus* through the milk touching upon the following points:

(1) The effect on rabbits, guinea pigs and calves respectively of feeding naturally and artificially infected milk.

(2) The significance of the matting of the hairy tufts about the orifice of the sheath and at the lower commissure of the vulva of calves.

While much of my time during the past year has been occupied in studying the subjects taken up in the above lists. I have kept in mind other branches of my general problems and have gathered data for different phases of this work. (L. H. Cooledge).

Mr. Cooledge submits the following report on investigations having in view the establishment of a proper basis for educational, extentional efforts in connection with the production and marketing of a clean and safe milk supply.

MARKET MILK CONTESTS AND DAIRY SURVEYS.

During the past few years many investigations have been carried on upon the effect of the presence of certain types of bacteria upon the milk. Some types have been found undesirable because they are pathogenic, others because of undesirable fermentations which they cause, while others are undesirable because their presence indicated that the milk has not been handled in a hygienic manner.

To keep undesirable types of organisms out of milk requires a good deal of care at every step in the production and handling. Obviously educational campaigns must be carried on among the producers and consumers of milk to show the value of certain sanitary practices. During the past year a study has been made of some of the methods used in stimulating interest in a pure milk supply. This study has been along the following lines:

Market milk contests.
Market cream contests.
Sanitary survey of milk plants.
Sanitary survey of dairy farms.
Sanitary survey of milk-plant water supplies.

As a result of these contests and surveys the writer is of the opinion that an occasional contest or sanitary survey carried on in the right manner will do more to interest the producer and consumer in a pure milk supply than will any amount of legislation.

The result of these contests and surveys follows:

In July, at the request of the Flint Board of Health, a sanitary survey was made of the milk plants and dairy farms furnishing milk in that city. A milk contest was also held.

The sanitary condition of milk plants as judged by the government score card for the purpose was fairly satisfactory. There is room for improvement, however.

SANITARY SCORE OF CITY MILK PLANTS (JULY, 1915).

Classified as,	Score.	Number of Plants.	Per cent total.
Excellent	90–100	0	0
Very good	75– 90	0	0
Good	60– 75	8	47
Fair	50– 60	7	41
Below passing	0– 50	2	12

Average score for city milk plants 58.3.

The sanitary condition of dairy farms was found to be slightly better than the city milk plants. A score card for dairy farms was used for this survey.

SANITARY SCORE FOR DAIRY FARMS (JULY, 1915).

Classified as,	Score.	Number of farms.	Per cent total.
Excellent	90–100	0	0
Very good	75– 90	1	2.5
Good	60– 75	21	52.5
Fair	50– 60	13	32.5
Below passing	0– 50	5	12.5

Average score for dairy farms, 59.4.

The milk contest held was different from the ordinary milk contest, where samples are prepared with great care and entered, in that the samples were taken from the milk wagons without previous warning. The scores represented the condition of the milk as it was being put on the market. In scoring milk the following things are taken into consideration—bacterial count, flavor and odor, visible dirt, fat, solids not fat, acidity and condition of bottle and cap. The result of this contest follows:

SCORE OF FLINT MILK CONTEST (JULY, 1915).

Classified as,	Score.	Number of samples.	Per cent total.
Excellent	90–100	1	5.5
Very good	75– 90	7	39.0
Good	60– 75	1	5.5
Fair	50– 60	8	44.0
Poor	0– 50	1	5.5

The results of this survey entitled "Suggestions Based upon a Sanitary Survey of Milk Plants and Dairy Farms Supplying Milk to the City of Flint" was published in a 12 page pamphlet by the Flint Board of Health and distributed widely among the dairy farmers of that vicinity.

September 14, a milk contest was judged for the Jackson Board of Health. This was the first time a contest of this kind had been held in this city and as a result the number of entries was small.

SCORES OF JACKSON MILK CONTEST (SEPT., 1915).

Classified as,	Score.	Number of samples.	Per cent total.
Excellent	90–100	3	43
Very good	75– 90	3	43
Good	60– 75	1	14
Fair	50– 60	0	0
Poor	0– 50	0	0

The writer acted as superintendent and judge of the State Fair Milk Contest. Samples of milk were entered by forty-six dairy farmers. Most of these were from farms in the neighborhood of Detroit.

That intelligent and painstaking care was used in preparing these samples is shown in the following table:

SCORES AT STATE FAIR MILK CONTEST (SEPT., 1915).

Classified as,	Score.	Number of samples.	Per cent total.
Excellent	90–100	14	30
Very good	75– 90	30	65
Good	60– 75	2	5
Fair	50– 60	0	0
Poor	0– 50	0	0

At the request of the Grand Rapids Board of Health a milk contest was held at that place in March. The samples entered in this contest scored as follows:

SCORES AT GRAND RAPIDS MILK CONTEST (JAN., 1916).

Classified as,	Score.	Number of samples.	Per cent total.
Excellent	90–100	11	41
Very good	75– 90	14	52
Good	60– 75	1	3.5
Fair	50– 60	1	3.5
Poor	0– 50	....	....

SCORES OF GRAND RAPIDS CREAM CONTEST (JAN., 1916).

Classified as,	Score.	Number of samples.	Per cent total.
Excellent	90–100	6	46.0
Very good	75– 90	4	31.0
Good	60– 75	2	15.0
Fair	50– 60	1	8.0
Poor	0– 50	0	0

In March a second milk contest was held at Flint. This contest included samples of milk which were carefully prepared for the contest and samples that were taken from the wagons without warning.

The samples in these contests scored as follows:

FLINT MILK CONTEST (MARCH, 1916).

Classified as,	Score.	Number of samples.	Per cent total.
Excellent	90–100	4	31
Very good	75– 90	6	46
Good	60– 75	3	23
Fair	50– 60	0	0
Poor	0– 50	0	0

(L. H. COOLEDGE.)

REPORT ON BACTERIOLOGICAL WATER ANALYSIS.

The bacteriological analyses of water are made under the direction of L. Zae Northrup, but those examinations made in connection with dairy surveys were conducted at the suggestion of Mr. Cooledge. Eighty samples of water were examined bacteriologically during the year 1915-16. Of these, 19 samples were from the city water systems from Flint, Saginaw, East Lansing and the College, the remaining 61 were from rural communities. Fifty or 63 per cent of all samples were polluted with sewage bacteria. Seven or 37 per cent of all city samples were sewage polluted and the remaining 43 polluted samples constituted 70 per cent of all samples analyzed from rural sources.

Twenty-one samples were taken from wells in use by dairies supplying Flint; this number includes three samples from the Flint city water supply. The average bacterial count of the latter was 16,693 per cubic centimeter and the samples were unquestionably polluted with sewage organisms.

The average bacterial count of the rural wells supplying dairy farms near Flint was 20,220 with a minimum of 31 and a maximum of 63,000 per cubic centimeter. Only two of the rural wells in this case would have been above suspicion. This condition obtains very commonly and is a deplorable one since the health, not only of individual families and of small localities, but of the public using milk from these dairies is endangered by these polluted water supplies. The universal contamination of these wells may be almost unmistakably attributed to the fact that they are surface wells.

Sixteen samples of water were collected for bacteriological analysis from the milk plants which supply the city of Lansing. These analyses were made by Mr. R. W. Wyant in connection with a sanitary inspection of the plants, which were scored by Mr. L. H. Cooledge. The table below gives the details of the scoring and the count.

Of these 16 samples, 81.2 per cent were grossly contaminated with surface washings or sewage or in some cases both. The average bacterial count of all samples was over 800 per c. c. with a minimum count of 4 and a maximum count of 116,200 per c. c. Fifty per cent of these samples would pass unquestioned from the standpoint of counts only. The prevailing comparatively low counts in the water supplies of Lansing's city milk plants without doubt may be attributed to the deep wells necessitated by the geological formation in this vicinity.

Sanitary score.				Count.			
Number.	Methods.	Equipment.	Total.	Agar.	Gelatin.	Agar shake.	Lactose bile.
1	28.0	17.0	45.0	0	23	Surface growth	No change.
2	25.6	18.5	44.1	417	7,000	Acid + gas	Acid.
3	20.5	15.5	36.0	44	4,740		Acid.
*3b				33	4,086	Acid + gas	Acid.
4	24.0	17.3	41.0	0	28	No change	Acid.
5	50.0	35.0	85.0	42	944	Acid	No change.
6	26.0	16.0	42.0	116,200	93,300	Acid + gas	No change.
7	21.0	13.0	34.0	110	27	Gas	No change.
8	27.5	18.0	45.5	160	24	Gas	No change.
9	21.5	15.5	37.0	3,000	4	Gas	Gas.
10	34.9	26.3	61.2	1,196	18,000	Reduction	No change.
11	33.7	29.1	62.8	9	966	Much gas	No change.
12	20.0	15.2	35.2	0	20	Acid + gas	No change.
13	27.8	24.0	51.8	90	205	Gas	No change.
14	16.8	17.2	34.0	90	456	Acid + gas	No change.
15	38.3	33.7	72.0	1	4	No change	No change.
16	19.0	13.0	32.0	134	745	Acid + gas	Acid + gas.

*Two wells.

The bacterial count of the agar plates, which are incubated at 37°C. indicates the number of bacteria in each c.c. of the water which may be of intestional origin or related forms.

The gelatin plate count gives the number of bacteria present which grow at lower temperatures and are for the most part soil or natural water organisms.

Gas and acid in the agar shakes indicate that there is at least one organism of the colon group present in 100 c.c. of the water.

Litmus lactose bile inhibits the growth of most bacteria not of the colon group; therefore growth in this medium suggests serious pollution.

The above table shows that only four plants out of the 16 examined score above 50. Plants scoring less than 50 should not be allowed to sell milk. In many cases carelessness was the cause of the low score. A general clean-up inside and outside of the building would, in most cases put the score up to 50 with little or no additional cost. The most noticeable feature of the above survey is the fact that 11 out of the 16 plants score under 50. (L. H. Cooledge.)

Mr. C. W. Brown has devoted approximately one-half of his time to Adams project 1b and the remainder to studies in the broad field offered by the nodule forming bacteria and vinegar and pickle fermentations. His report is given below and includes mention of work done under his direction by graduate students and assistants:

Under the Adams project, Keeping Qualities of Butter, parts IV, "Cream Ripening and Its Influence" and V, "Pasteurization and Its Influence," represent work done on the same samples and will be offered soon in bulletin form for publication.

A contribution to part IV, which has for its purpose the following of various groups of micro-organisms from the cream to the butter, represents the data secured by Kurt Peiser in his study under my direction for a Master of Science degree, arranged and discussed in bulletin form and presented for publication.

A contribution to Part V which has for its purpose the study of factors influencing the resistance of bacteria in cream to the heat of pasteurization is assembled and arranged from a part of the work done for a Master of Science degree by Mr. Peiser. This also is offered in bulletin form for publication.

During the year work on part VI "The Study of the Micro-Flora of Butter" has been continued. The object here is to ascertain the individual action of a number of the micro-organisms commonly found in butter upon the constituents of milk in order to obtain a better understanding of their action in butter. This work is not ready at present to offer for publication.

Additional data have been added to the, "Study of Starters." This work is, in reality, a branch of the main subject and, when completed, can be presented logically under the head of "Keeping Qualities of Butter."

The data upon the "Fermentation of Brine Pickles" secured during the year is being assembled in bulletin form for publication, but is not ready for presentation with this report. The object of this work is to determine the nature of the normal fermentation in order that abnormalities may be adjusted and that much of the spoilage may be prevented.

The work upon the "Viability of *Ps. radicicola* under Aerobic and Partial Anaerobic Conditions" has been pursued under my direction by F. O. Ockerblad as part requirement for a Master of Science degree. As soon as it can be arranged in bulletin form it will be offered for publication. The purpose of this work is to study the conditions affecting cultures of nodule-forming bacteria and to ascertain their wellfare when distributed for seed inoculation.

The distribution of cultures of nodule-forming bacteria, of lactic bacteria, of the alcohol-acetic micro-organisms, and of pure cultures from stock room for commercial, experimental or educational purposes has been conducted largely by Mr. Ockerblad, assisted by Mr. C. G. Nobles. The number of different cultures sent out from this laboratory during the year is tabulated as follows:

CULTURES OF NODULE-FORMING BACTERIA SENT OUT DURING THE CALENDAR YEAR 1915 AND UNTIL JUNE 30, 1916.

	Jan. 1, 1915 to June 30, '15.	July, 1915.	August, 1915.	Sept. 1 to Dec. 31, '15.	Total for 1915.	Jan. 1 to Apr. 30, '16.	May, 1916.	June, 1916.	Total Jan. 1 to June 1916.
Alfalfa.......	3,042	601	1,104	106	4,853	1,071	658	511	2,240
Sweet clover..	323	38	39	10	410	395	157	54	606
Red clover....	375	30	92	12	509	338	99	21	458
Alsike clover..	33	1	4	2	40	39	22	2	63
White clover..	14	2	....	....	16	4	....	....	4
Field beans...	241	....	....	....	241	2	44	228	274
Garden beans.	17	....	....	....	17	3	2	....	5
Soy beans....	738	56	....	....	794	21	214	301	536
Canada field pea........	191	15	....	....	205	120	20	10	150
Garden pea...	34	....	....	....	34	8	11	....	19
Cow pea.....	225	8	....	....	233	16	22	57	95
Sweet pea....	15	....	....	....	15	10	3	1	14
Vetch........	92	63	353	104	612	25	23	5	53
Totals...	5,340	814	1,592	234	7,979	2,052	1,275	1,190	4,517

Cultures of other micro-organisms were sent out from this laboratory between June 30, 1915, and June 30, 1916, in the following numbers:

Alcohol-acetic	14
Bact. lactis acidi	9
Bact. bulgaricum	19
Miscellaneous from stock room........	77

Connected with the distribution of alcohol-acetic cultures a number of samples of vinegar sent in from different parts of the State were analyzed and the results with suggestions returned. (Chas W. Brown.)

Mr. Morgan has continued his studies with the soil solution and its method of extraction as devised in this laboratory. I feel that progress is being made in this work. His report follows:

The data derived from the study of the soil solution obtained by the oil pressure method is now ready for publication. The experiments as reported a year ago showing the results of the action of micro-organisms upon nitrogenous compounds, as dried blood, tankage, cottonseed meal, were continued together with others showing the effects of the micro-organisms upon ammonium sulfate and sodium nitrate and phosphate rock.

Mr. O. M. Gruzit, graduate assistant in this department, has shown, in his study of the effects of some acids, alkalis and inorganic salts on soil bacteria in soil solution, that these soil bacteria in the few soils used developed best when the reaction was N/1000 alkaline (-1° Fuller's Scale). An acid reaction of N/1200 killed about 98 percent while an acid reaction of N/2860 inhibited the growth of 46.5 percent of the bacteria in soil solution.

It has also been found that the reaction of the soil solution changes gradually from alkaline into an acid condition due to bacterial activities. The effect of the various potassium, nitrate and phosphate salts did not show great differences upon the number of bacteria, but it did show that the medium became toxic to bacteria at different times depending upon the salt present.

All this work and that of the effect of the micro-organisms upon various fertilizers in soil will be taken up in detail in a publication in the near future.

About a year ago with your consent, the writer in co-operation with Mr. W. S. Robbins, at that time connected with this department in the manufacture of hog cholera serum, now with the Pathological department, took up the study of the growth of the hog cholera virus in the soil solution as a preliminary to the study of soils infected with said virus. Some progress has been made in the work thus planned. The work has been delayed somewhat for lack of material.

At the meeting of the American Bacteriologists, held at Urbana, Illinois, December 28-30, 1915, the writer presented a paper entitled "The Soil Solution as an Index of the Biological Changes in the Soil" and in conjunction with Mr. Gruzit, "Reaction of the Soil Solution as an Index of the Biological Changes in the Soil." Abstracts of both papers appeared in the first number of the "Journal of Bacteriology." Mr. Gruzit presented a paper on "The Effect of Natural and Modified Soil Solution on Bacteria" at the meeting of the Sanitary Section of the Michigan Academy of Science held at Ann Arbor, March 29, 1916. (J. Frank Morgan.)

Mr. L. C. Ludlum came to us in September, 1915, from the University of Michigan, to take up the work in hog cholera research suspended in March of the same year by the resignation of Dr. L. R. Himmelberger. These breaks in the continuity of research problems are unfortunate, creating, in many instances, delays in the progress of the work due to the necessity of breaking in new men, that are far more expensive than the increment in salary essential to the retention of a good man already familiar with the project. We are pleased with the manner in which Mr. Ludlum has taken up his duties. His report follows:

"My work has been almost entirely in the field of pathogenic bacteriology, with some aspects of hog cholera as the main problem. The first three months were largely spent in reviewing the literature of hog cholera.

The research work on hog cholera has been pursued with four definite ideas in view, viz.:

First: Cultivation Experiments. The artificial cultivation of the filterable virus of hog cholera has never been accomplished. Success in this attempt would open the way to much valuable work in this and related fields.

Filtered virus blood and filtered virus salt solution will be used in media of various kinds. The methods of Noguchi, successful in the artificial cultivation of certain anaerobic, filterable organisms, will be carried out.

Second: Development of an early and accurate laboratory diagnostic method for hog cholera.

The isolation or extraction of the specific casual agent of hog cholera would give us an antigen which might prove of value in agglutination and complement fixation tests with virus serum.

Different extracts of various organs and tissues of virus hogs will be tried out in the attempt to secure such an antigen.

Third: If the artificial cultivation experiments should be successful, then we would have an excellent basis for a rational vaccine treatment for hog cholera. Such a treatment, with the more or less permanent immunity usually obtained in such treatment, is to be distinguished from the Dorset-Niles protective serum and the resultant very temporary, passive immunity secured with serum-alone treatment.

Fourth: With the perfection of a method of complement fixation, as noted under Experiment 2, there is a possibility of working out a cheap and quick method of standardizing the Dorset-Niles serum. Just at present this is the greatest improvement that can be hoped for in the Dorset-Niles treatment.

While no final report on any part of the work is yet desirable, some points may be worth touching upon.

The cultivation experiments,—by no means complete as yet,—were carried out with samples of virus defibrinated blood, virus serum (from clotted blood) and virus salt solution obtained by the method of Robbins and of Craig. These solutions were filtered, in dilutions of 1 to 3 with normal salt solution, through Pasteur-Chamberland and Buchner filters. Bacterial sterility was proven by inoculation tests in the ordinary media, and then attempts were made to cultivate the virus on various special media, under aerobic and anaerobic conditions, and at various temperatures.

The virus salt solution proves the easiest to handle, because of many difficulties encountered in filtering the blood samples. No definite results can be reported, but the tests at different temperatures will be carried out more completely another year.

In the endeavor to apply the method of complement fixation to the early diagnosis of hog cholera, various extracts were tested for antigenic properties, using immune, hyperimmune and virus sera for specific amboceptor. This is a reversal of the ordinary complement fixation technic and takes for granted that if the method is applicable at all, these sera should contain such a specific lytic amboceptor for the specific virus of hog cholera.

Various extracts of diseased organs from hog cholera animals were used. Some definite results were obtained with such organ extracts, but the fact that almost invariably such organs are contaminated with *B. cholerae suis*, renders this work uncertain. Using a pure culture of this organism it is possible to obtain complement fixation with some samples of hyperimmune sera.

It seems probable that the most definite results will be obtained with an antigen prepared from virus salt solution. This fluid can be obtained free from *B. cholerae suis* contamination, is powerfully virulent for susceptible hogs and a concentrated salt virus should contain enough of the specific virus to give antigenic properties. The results here are promising but not complete.

It is necessary to have enlarged facilities for experimental animals to carry out this work at all satisfactorily and the new building now being erected will soon render this possible.

Another problem taken up during the year was that of white diarrhea in chicks. This disease was first studied in the eastern states about ten years ago and has been the subject of extensive reports from the New

York (Cornell), Connecticut and Massachusetts Experiment Stations. There is reason to believe that the disease is quite prevalent in this State and steadily becoming more serious to the poultry industry, probably due to importations of diseased breeding stock from the east.

It seems advisable to make a complete investigation of this problem, including a survey of the State in respect to the present spread of the disease and also if possible to perfect diagnostic and preventive methods or curative agents with the idea of identifying and, if possible, stamping out the disease.

It seems possible to adapt the complement fixation method to the diagnosis of this disease in adult carriers, as preliminary work has demonstrated.

A considerable amount of outside clinical diagnostic work has been handled throughout the year. (L. C. Ludlum).

We hope to be able to continue the work with white diarrhea of chicks and arrangements have been made to place the problem in the hands of a graduate assistant and to cooperate with the Poultry department of this Station.

While still connected with this laboratory Mr. W. S. Robbins, in charge of the hog cholera serum plant, conducted some experiments with virulent salt solution that have remained unpublished. He was able to find that the virulent salt solution (25 cc. salt solution per pound of body weight remaining in the abdominal cavity 6 hours) would hyperimmunize a pig successfully when injected subcutaneously but not when injected intravenously in reasonable or practical amounts. He attributes the success of the subcutaneous injections to the perfect absorptive powers of the salt solution virus due to its low fibrin and protein content as well as low *B. cholerae suis* content as compared with virulent blood. He found the composition of the 25 cc.-6 hour salt solution to average, in comparison with the blood of the corresponding animals, as follows:

	Percentage recovered.	Percentage fibrin.	Percentage protein.	B. cholerae suis per cc.
Virulent salt solution	61.4	.067	.99	3
Virus blood		17.75	.62	6,468

Adams project 3b, bovine infectious abortion, has suffered during the year due to our inability to fill the vacancy caused by the removal of Dr. Hallman to the Department of Animal Pathology, newly created. While we congratulate the College on its acquisition we deplore the loss to the Station. Dr. Hallman's results are to be found in the "Journal of the American Veterinary Medical Association," N. S. Vol. 2, No. 3, June, 1916, "Studies in Infectious Abortion in Cattle." Ward Giltner, E. T. Hallman and L. H. Cooledge. The main facts are as follows:

"The use of living cultures of the abortus bacterium on open females and dead cultures on pregnant females, has been applied to a few herds with the object of observing their pyrogenic and immunizing effects.

"Not a large enough number of animals have been under observation to make any valuable deductions, nor has any herd been treated with a part of the herd left as controls. It has been difficult to get owners to agree to have a part of their herd untreated, and difficult to get them to record temperatures for several days after the injections.

"The method of treatment adopted was to cultivate the organism on neutral agar until considerable growth had occurred; these were then washed off with sterile salt solution, and diluted so that there were approximately 4 to 5 billion organisms per c. c. Where dead cultures were used the suspension was heated to a temperature of 60°C. for one hour and transfers made to agar to determine their sterility. Where the living cultures were used, they were injected within a few days from the time the dilutions were made.

"There is little in our work to encourage one in the use of dead cultures, and there is reason to believe that injury may result in some cases from the use of living cultures. Nothing but an extensive series of carefully conducted experiments will demonstrate the actions of these injections.

"In one herd we have recorded the following observations: Of 19 animals receiving living cultures at the 1st injection, 4 gave a marked thermal reaction; 11 gave a slight thermal reaction and 4 gave no thermal reaction.

"Of the 17 animals receiving dead cultures, 7 gave a slight thermal reaction, and 10 gave no thermal reaction.

"Of 15 animals not reacting to the test and receiving injections of living cultures, 9 having calved normally only after experiencing considerable difficulty in getting them with calf; 3 have aborted; 1 has been sold without learning subsequent history and 2 are sterile. Of 2 animals reacting to the test and one suspicious and not tested, all calved normally.

"Of 10 pregnant animals reacting to the test and receiving injections of dead cultures, 4 have aborted, 4 have calved normally, and 1 died on the 228th day of gestation with a normally developed calf in utero.

"Of 6 animals not reacting to the test, and receiving dead cultures of the abortus bacterium, 3 have calved normally and 3 have aborted. One giving a suspicious reaction to the test, calved normally."

We have continued to maintain our experimental herd which was available for project 1a and we have supervised some experimental work along the line of a study of the bacterial flora of the generative organs in health and disease. Mr. H. J. Stafseth, graduate assistant, and Mr. W. C. Keck have undertaken this work, which will be continued. They have found a similarity in flora in the vagina of healthy cattle in our herd and in the uterus of cattle killed in the packing houses at Chicago and Detroit. Mr. Huddleson finds abortus-like culture in the cysts of diseased ovaries but fails to find antibodies for *Bact. abortus* in the cystic fluid. A further study of the cystic fluid is being undertaken since we are convinced that a relation exists between ovarian degeneration and infectious abortion. These men have made the serum tests on samples of bovine blood.

There have been tested during the year, 202 samples of blood (exclusive of experimental samples) by the complement fixation test for infectious abortion, of which 99 reacted and 94 failed to react, with 9 suspicious. In one instance 14 duplicate samples were sent to another laboratory with the ultimate results coinciding perfectly.

We are now having built a barn which will satisfactorily house our experimental animals and enable us to conduct our work in the future under pleasanter surroundings. A new man is expected in September to take up, and push with vigor, the research work with this disease.

In conclusion I wish to commend the earnest efforts and fine spirit of cooperation manifested by all those whose work is discussed herein. I am indebted to Miss Northrup, assistant bacteriologist, for advice and assistance freely given out of time already fully occupied by teaching duties, and in behalf of the laboratory I must thank Miss Louise Rau for her industry, patience and carefulness in handling all the numerous details of office work made necessary by the variety of our endeavors.

We are especially grateful to you for your active support and wise council during the year.

Respectfully,
WARD GILTNER,
Bacteriologist.

East Lansing, Mich., June 30, 1916.

REPORT OF THE BOTANIST.

Dean R. S. Shaw:

Dear Sir—I hand you herewith my report as Botanist of the Experiment Station.

The botanical staff has suffered no loss during the year, consisting as in the preceding year of myself, Dr. G. H. Coons, Research Assistant in Plant Pathology; Dr. R. P. Hibbard, Research Assistant in Plant Physiology; and Mr. J. H. Muncie, Assistant in Plant Pathology. In addition Mr. R. W. Goss was employed during the fall for full time and from January 1st on as half time Assistant in Plant Pathology. For assistance in making culture media, distilled water for Dr. Hibbard's experiments, and other work of the kind, student labor has been employed as it was needed or was available.

My work in the main consisted of the general supervision of the lines of work carried on by the above named staff. In addition I had charge on the part of the Experiment Station of the cooperative work on cucumber diseases.

The reports of Dr. G. H. Coons, Dr. R. P. Hibbard and Mr. J. H. Muncie are appended herewith as part of my report.

The cucumber disease work is conducted under a cooperative agreement between this Experiment Station and those of Wisconsin and Indiana, the Bureau of Plant Industry of the U. S. Department of Agriculture, and the H. J. Heinz Pickle Co. Under the terms of this agreement the H. J. Heinz Pickle Co., furnishes the land and labor at Big Rapids, and pays the salary of Mr. S. P. Doolittle on the H. J. Heinz Industrial Fellowship at this institution. The Bureau of Plant Industry furnishes several men with W. W. Gilbert to supervise and coordinate the work. For this Station I supervise and plan the work of Mr. Doolittle on the mosaic disease of cucumber and act in an advisory capacity in formulating the general plan of the work. In this latter capacity I went to Pittsburg in January for a conference of all cooperating parties.

In the prosecution of these investigations Mr. Doolittle has determined the infectious nature of the mosaic diseases of cucumber; showing that it can be carried from a diseased plant to a healthy plant by plant lice. The organism causing the disease has not been isolated as it has not been possible to cultivate it so far. It is exceedingly minute, passing through the ordinary bacterial filters, constituting thus a so-called "filterable virus." The disease is transmissible by aphids, or by hypodermic injection of an extract of a diseased plant, from cucumber to muskmelon and squash and vice versa. Further experiments on other hosts are in progress, as well as experiments to determine the means of over-wintering.

One of the most important pieces of work that can be undertaken is the plant disease survey of Michigan. Up to the present the necessary funds have been lacking, so that it has been impossible to make such a survey in a systematic manner. However, it is possible to get an idea of what are the more pressing plant diseases from the letters and other inquiries that come to the College. Occasionally diseases new to the State or even to science are brought to light through such correspondence. It is greatly to be deplored that not all the correspondence on plant disease topics and specimens of plant diseases sent in are turned over to this department. At present at least two other departments make it a practice to answer such letters and make no records and do not preserve the specimens. These records and specimens would add greatly to the completeness of our information on this subject. It is furthermore regretable that such letters are not all referred to this department since, through unfamiliarity with the current literature on plant diseases on the part of those departments, the diagnoses made and the control measures advocated are not in all cases entirely trustworthy and often are at variance with the findings and recommendations of this department.

It must be conceded that these departments had in the past an excellent reason for occupying this field in view of the fact that plant pathology was not in the hands of a trained pathologist in this department, but that time has long passed and efficiency and accuracy would seem to require that *all* letters and inquiries even of the simplest nature, on plant diseases be referred to this department. This should be viewed by these other departments as a measure of protection to them as it is obvious that they will thus be relieved from the danger of making false diagnoses.

It would seem highly desirable to establish a plant survey project in this department either in the Experiment Station alone or in cooperation with the Extension Division. The object of such a project would be "To give instruction and practical demonstration in the identification and control of plant diseases, including advice through correspondence and personal visits to farms and orchards, in cooperation with county agents, farmers' organizations, and individuals." Special attention would be given to certain of the more important crops. In the course of this work correspondence would be followed up by personal visits to various districts, and the systematic visitation of farms in different regions would be made. As a result the most pressing problems would be discovered and material and opportunity obtained for further work. The methods of procedure proposed are as follows:

(1) It is proposed to give instruction in the serious diseases of crops by local meetings and by field surveys, wherever the localization of the industry is such as to make these efficient. For example, instruction and demonstrations in control of celery diseases can readily be undertaken in each of the great celery districts and these courses of instruction and demonstrations there will reach the great majority of the growers. The other crops are more or less localized and afford somewhat similar possibilities of economy of effort in reaching the growers concerned.

For much of the work the system of farm demonstration will be employed. This will consist in the establishment of demonstrations on particular farms of strategic location, combined with careful supervision to insure as successful outcome as possible. For example, in cucumber diseases, it is now known that a careful rogueing of the fields by one familiar with the early stages of such diseases as wilt and mosaic will do much to insure a crop. The selection in certain pickle growing districts of farms for this purpose, will demonstrate the value of this treatment.

Further there are possibilities in working through the county agents of co-ordinating and enlarging such of their work in plant disease control as should be a part of good farm practice. This work would be so constituted as to relieve the county agent rather than to add to his burdens. For example, in the case of a fight against bean diseases, a demonstration will be planned in which safe seed, etc., will be planted for contrast with the ordinary run of seed. The plans will be formulated and carried out in the counties interested. The leader will visit these county men and personally assist in the establishment of the demonstration. The collection and co-ordination of results is also contemplated.

(2) The selection of 10 to 20 farms representative of the different sections of the state and its major crop interests, to which regular visits may be made during the growing season, the purpose of these visits being to keep in touch through these agencies with any peculiar local plant pathological problem and to forsee epidemics.

(3) The handling of correspondence relative to plant disease control in Michigan. This seems to include diagnosis, recommendation and recording of occurrence. Where conditions warrant, the recommendations will be followed up by letter or visit to find value of treatment or cause of failure.

(4) The establishment of specialized mailing lists of growers interested in special crops. These men will receive special extension service letters which may be issued from time to time. Such lists would be available in sending the publications of the scientific staff. Further, the establishment of suitable collections, charts, lantern slides, etc., to promote the work is proposed.

(5) Cooperation with existing agencies of agricultural instruction, county agents, schools and normals, in giving demonstrations, and field

instruction in plant disease control or in the identification of diseased specimens. Upon request of the county agents the leader in extension in plant disease control will plan to make a special visit to assist in demonstrating any particular matter of disease control, or to survey the field for future plant disease demonstrations. He will also serve as the agency for bringing the research agencies of the College in touch with field conditions.

(6) It is proposed to furnish leadership in community effort against plant disease outbreaks or epidemics. For example, in the diseases of celery, especially blight and "stunt" (a new soil sickness) community effort will be enlisted to make the fight efficient. So, too, in all those diseases in which the destruction of the sources of infection is the principle involved.

Respectfully submitted,
ERNST A. BESSEY,
Botanist.

East Lansing, Mich., June 30, 1916.

Dr. E. A. Bessey:

Dear Sir—At your request I submit a report of the work done during the past fiscal year. My work, as before, falls under two heads: that done for the College and that done for the Experiment Station. The work for the College is divided into several forms of activity: teaching classes in Plant Pathology, assisting with graduate work, and assisting in the extension phase of the department's work. Statistics of the undergraduate and graduate teaching are included in your department report. The extension work has consisted, in part, of attention to correspondence with reference to plant diseases. During the year nearly a thousand plant disease specimens have been handled in the laboratory. Besides this work several popular lectures have been given at meetings of farmers. Exhibits of plant disease specimens have been prepared and these have served as a loan collection for the fairs, special extension trains, and for the general use of county agents. A collection of lantern slides on the late blight of potatoes has been assembled, and this with proper descriptive legends has been put at the service of the county agents. The department's interest in potato-disease extension work has been continued. In this connection students have been trained for field inspection and advice has been given on the policy of the work. This cooperation with the leader of the potato extension work has given results which warrant suggestions on the problem of co-ordination of a college department with the extension service.

The work done for the Experiment Station falls under three heads, that done under the (1) Adams fund project, (2) the Hatch fund project, and (3) the various State fund projects.

(1) The Adams fund project, which has been under way in the laboratory for several years, has reached a point where definite conclusions have been arrived at and where fairly complete presentations can be made. This project has been terminated. It may be permitted to review hastily this work, summarizing the main results.

The problem in general dealt with the determination of the cause and control of certain limb and twig diseases of fruit trees. In particular, attention was concentrated on a serious canker disease which appeared in apple trees in Northern Michigan. The canker was different from any of the known cankers of apple, being distinct in the character of the lesion produced. Bark on affected limbs was killed to the wood and after a year or two the killed bark peeled in strips leaving a decorticated branch on which the causal organism commonly fruited. The associated organism was obtained in pure culture, its morphology determined and the etiological relationship established. The organism proved to be a member of the great group of Fungi Imperfecti, the Sphaeropsidales. It seemed to correspond exactly with a fungus from apple which Saccardo found in Italy many years ago and which he described under the name of Aposphaeria fusco-maculans. For reasons outlined in another publication, the organism was transferred to another genus and now is called Plenodomus fuscomaculans. This phase of the subject has been reported in a preliminary way in the 1915 Report of the Michigan Academy of Science. Due to unfortunate delays in publishing this report this preliminary paper has not as yet been distributed. It was also reported in abstract form at the Columbus meeting of the American Association for the Advancement of Science. This abstract has appeared in Science, March 10th, 1916.

The greatest emphasis in the study of this fungus has been placed upon the physiological activities of the parasite. This work was done in part at the Cryptogamic Laboratory of the University of Michigan. This phase of the work has appeared in the Journal of Agricultural Research, January 17th, 1916.

The final publication on this project will consist of a technical bulletin dealing with the organism as a plant pathogene. This work has been completed but due to press of other work has not been put into final shape for publication.

With the accomplishment of these results the present Adams project was terminated, and a new project planned. This project is a natural outgrowth of the physiological studies already carried out.

The formal statement of the object of the project is as follows:

"To determine with some of the plant pathogenes of the Fungi Imperfecti, biological relations which may give a basis for identification and classification as well as understanding of physiological and life history problems. The Fungi Imperfecti form a group which at present has no basis for classification other than a highly artificial one. Attention will be concentrated on the section of the group represented by the genus Phoma and its close allies."

(2) HATCH FUND.

Plant Disease Survey.

The work under the Hatch fund has continued along the same lines as in previous years. The plant disease survey of the State has been continued. In making this survey the extensive correspondence of the department on plant diseases already referred to was found to be an invaluable adjunct.

The work on the plant disease survey has been further carried on by means of questionnaire letters and by field trips to various parts of the

State. The tabulated results of this survey have been forwarded to the Bureau of Plant Industry at Washington. Some of the interesting observations and new diseases of the State are briefly mentioned in a supplementary article in this report.

Other Work with the Hatch Fund. Superintendence of the cucumber project in which the department is co-operating with the U. S. Department of Agriculture was carried out by means of the Hatch fund. The report of progress of this work is given at another place.

Many minor problems are handled under the Hatch fund. The accumulation of photographs to illustrate the signs of the various plant diseases of economic hosts is financed from this fund. At present the number of usable negatives on plant diseases is about 500.

(3) STATE FUNDS.

Bean Work. The extensive investigation of bean diseases and their control which was begun in 1913 at the appointment of J. H. Muncie has now reached a stage where definite lines of advance can be seen. The history of the project may be briefly reviewed. The bean crop of Michigan has long been a staple, leading crop in the State. In many sections it is the money crop. Year after year the average "pick" per bushel kept increasing and with seasons of abundant rainfall, the crop was unprofitable. The cause of this situation was clearly seen by Dr. Beal and his associates who had collected the causal organism as long ago as 1889. In face of repeated warning no work was done on the diseases and no explanations of the cause of trouble given publicity. In 1911 the evidence of great loss to the bean industry was apparent, but upon making a survey of the situation by visiting elevators and growers, it was plain to see that few if any knew the cause of "cull" beans. No control measures were consistently followed by the farmers. The consensus of opinion was that spotted, blighted beans were caused by the weather. It was not uncommon in 1911 and 1912 for elevator men to send in samples and upon receiving reply to doubt the correctness of the diagnosis and appeal to the U. S. Department of Agriculture for confirmation. When some of the leaders among the elevator men became impressed with the nature of the trouble they asked for help in the solution of the problem. The appointment of a special investigator was the outcome of the situation.

It was seen that the disease was introduced each year with the seed and accordingly attention was focused upon seed treatments. In 1911, I had attempted disinfection by chemicals and by hot water, and had also attempted specific-gravity separations of healthy and diseased beans in order to clean the seed stock. This work had yielded promising results. Spraying was tried and was found of no value.

With the appointment of a special investigator, experiments on seed treatments were continued on a large scale. In spite of more than two years of effort we are not able to report any seed treatment which is worthy of recommendation. In such diseases as oat smut simple surface disinfection gives efficient results due to the superficial nature of the contamination. In the case of bean anthracnose and bean blight, the contamination has either penetrated deep into the cotyledons or else is beneath the skin and between the cotyledons. It is out of the reach of any chemical so far tried. Hot water treatments, effective for wheat loose smut, fail to be practical in the case of the bean diseases, not only because of swelling of the seed coats when wet, but because the threads of the fungus and the blight germs are more resistant to wet heat than the bean itself,—the temperature which disinfects kills the beans.

It is needless to say that such on outcome of several years' work is discouraging, yet in the face of these results we are able to point out the value of the other lines of control undertaken.

Very early our attention was called to the high yielding quality and the general cleanness of the Early Wonder Bean, developed from the progeny of one plant by Mr. Mansfield of Remus. The character of this bean and its behavior were outlined by Mr. Muncie in the report for last year. This strain was found to be exceptionally pure and true to the original type. Unlike the general run of field beans in the State it was not, as yet, badly mixed. This bean has been found to be a heavy yielder and while not disease resistant, it is *disease escaping* due to its extremely short ripening season. The Early Wonder beans ripen from 10 days to 2 weeks earlier, and produce 8 to 10 bushels more per acre than field-run seed. When it is remembered that with an ordinary season much of the staining and discoloration takes place the last few days of the season, the significance of even, early ripening is apparent.

As a result of the efforts of the department this bean has been introduced in many bean-growing sections. In a two-year field test it has borne out its recommendation. While not perfect, it is safe to say that a replacement of Michigan seed stock by Early Wonder beans would cut the loss from bean diseases in two. There will be planted in Michigan next year about 1,000 bushels of Early Wonder beans. Each year the number of bushels of this seed available for planting will increase and the acreage likewise. The directional help given this phase of the bean work is going to give results.

In 1914 a small quantity of Early Wonder beans were sent to a grower in western Washington. He reported an excellent crop practically free from disease. He saved seed and planted again in 1916. The yield from the beans the second year was estimated at 30 bushels per acre. The beans grown were free from anthracnose and almost free from blight. Field-run western beans of this test were cleaner than any table picked Michigan beans.

The importance of dry summer conditions in cleaning up seed stock being demonstrated, we have advocated the utilization of this fact to clean up the seed stock for Michigan planting. It is necessary to send *Michigan* beans there for renovating, since native western seed when tried in our fields failed to ripen. Test quantities of Michigan beans have been sent to Idaho this year for growth under irrigation. This seed when brought back to Michigan should give fields cleaner than those from ordinary handpicked seed. This extensive experiment is now under way in co-operation with the U. S. Department of Agriculture. We see great possibilities in the method. When beans can be grown so that without any handpicking they are better than our best handpicked seed, it would seem that we must utilize this great renovating method. It may be pointed out that the seed companies have long been renovating garden beans by exactly this practice. One of the large seed companies of the State has already grown Michigan beans in Idaho. About 100 bushels of this seed, which, without hand picking showed only 5 slightly stained beans, probably blight, in a test sample of 2,000 seeds, have through the efforts of the department been placed in the bean growing counties of the State, for field test along with local seed. As a further check on this seed and on the Early Wonder bean, quantities sufficient for field test of northern grown and of clean picked seed have been sent out. The results of this experiment should show the correct practice for Michigan.

The part of the Bean Disease investigation which has borne the biggest results is the educational work which was promptly undertaken. The department issued a popular bulletin teaching how to determine the diseases and emphasizing the importance of just as clean seed as possible. It offered to analyze bean samples and determine the percentage of diseased and clean seed. Farmers and elevator men have sent in to date more than 2,000 samples of beans for this testing. When we remember that a sample commonly represents many bushels, all of which are for seed purposes, the direct value of this phase of the bean disease work is evident.

But the greatest value of the work comes from the education of the grower which has taken place. Before the inception of this work the belief was fixed that the trouble was sure to come if the weather was wet. This opinion was firmly held not only by growers but by elevator men as well. Clean seed was good if you could get it, but the enormous superiority of clean seed was not realized. Bean Blight and Bean Anthracnose are now household words in the bean districts. Growers and elevator men can analyze samples and detect unsafe seed almost as accurately as a trained plant pathologist. The former president of the Michigan Bean Jobbers Association is authority for the statement that the second year after the starting of scientific work on bean diseases by the College, the jobbers put on the market, for one season's planting, more than 100 cars of choice carefully picked beans taken from the best stock obtainable. He stated that *this was done to meet a demand from the growers who had been led to see the necessity of safe seed stock.* The chief topic of conversation at bean jobbers' conventions is clean seed for planting and where to get it. Elevator men are making every effort to have every farmer in their districts plant only seed which is safe. This change in attitude has come as a result of the propaganda directed by the College. It is true that the diseases have been severe,—the losses have raised the question and made growers ready to listen. But these losses came years ago without any awakening of the growers and without any definite constructional work. It is evident that timely information consisting of workable, practical measures has started this great change in practice in the bean growing sections.

Potato Work. Last year the Fusarium wilt project was established by the State Board. This work has been done by Mr. R. W. Goss. He reports satisfactory progress on the study of the fungus causing the disease. Attention has been concentrated on the clearing up of questions of identity of the organisms isolated from various types of vascular discoloration. The net outcome of these studies has been to show that Fusarium wilt is present in a large percent of our field stock and to enable us to diagnose accurately the symptoms found in light attack.

By infection experiments with potato tubers at different degrees of humidity and at a range of temperatures, the fact has been established that Fusarium oxysporum is an important agency in causing tuber rots, but its activity depends upon high temperature and high humidity.

The toxicity to the potato vine of filtrates from old cultures of Fusarium has been proved conclusively. Synthetic solution in which the potato Fusarium had been grown for some weeks was filtered from mycelium and spores by means of a Berkefeld filter. Cuttings from healthy vines when placed in this filtered solution wilt in less than 24 hours, while checks in both distilled water and in sterile synthetic solutions remain turgid. These results are of far-reaching importance in contributing to our knowledge of the cause of the wilt produced by this fungus.

The field studies with this disease have already yielded results of practical value. By plot tests, tubers which were freed from infection by cutting off diseased parts were compared with whole tubers and the superiority of the former has been conclusively shown. The infected butt-pieces showed a practical failure when planted.

For ordinary agricultural practice this warrants the recommendation to reject a one-inch slice from the butt ends of potatoes in process of cutting for planting. This practice is being given a further test the present season. Mr. Goss is planning to complete the work on Fusarium wilt at the University of Wisconsin next year, in pursuance of studies for a higher degree.

Celery Work. In the report for last year an outline of the serious soil disease of celery was given. This stunting disease has been studied during the past fiscal year and control measures on a still larger scale than previously tried were undertaken. One-third acre of infected soil was steamed this past spring and demonstration was made that, with equipment in good running order the steaming can be done at a cost of less than $150 per acre. This lowering of price per acre comes from the use of large steam pans. These large steam pans are arranged to be lifted by levers and moved on wheels which run upon planking. Each pan covers nearly 100 sq. ft. at one application.

The celery work has now reached a stage where it can be successfully carried to the growers. We believed we are justified in beginning a campaign to lead owners to steam their fields where the infection is showing only in spots. These spots are of course a source of danger to the rest of the fields and it is only a matter of time until the disease completely infects the now slightly infected areas.

Attention has also been given to the Septoria Leaf Spot disease of celery commonly known as Blight. Study on this disease was carried on by Mr. Ezra Levin during the last summer. The work begun by him was completed in the winter and a special bulletin detailing the practical applications of the work has been prepared and given wide distribution in celery-growing centers. The work on the Septoria disease was especially timely, since the late celery crop of Michigan was a practical failure last year due to this disease. On a small acreage sprayed under the direction of this department the cooperating grower saved a crop worth $1500. This bulletin has been printed in both English and Dutch editions. Dr. Richard deZeeuw of this department kindly prepared the Dutch edition.

A serious root rot of celery caused by an undescribed species of Phoma was discovered at Kalamazoo. The etiological relation of the Phoma has been proved. Further study of this fungus is now being planned.

Completion of the celery project is contemplated for this next year, and it is hoped that funds will be provided so that the serious celery diseases can be investigated.

The division is cramped for room, not only in laboratory but also in greenhouse. The growing needs of our work should be recognized in the building program of the College.

Very respectfully,
G. H. COONS,
Research Assistant in Plant Pathology.

East Lansing, Mich., June 30, 1916.

NOTES ON MICHIGAN PLANT DISEASES FOR 1915.

POTATO DISEASES.

The peculiar inheritable malady of the potato known as Potato Mosaic was found very widespread in the Upper Peninsula. In one field 80% of the vines showed the disease, and the yield was cut more than half.

Another disease of the same type was found at Manistique. A certain shipment of Russet Rural potatoes has consistently thrown a number of plants for the last two seasons showing a peculiar proliferation of the shoots. The potato vines lose nearly all their characteristic appearance and become stunted clumps made up of a great many wiry shoots. The leaves are so small, that the vines take on the appearance of a clump of chickweed. The disease differs from the spindling sprout disease described by Stewart, in that a sort of witch's broom is produced instead of merely a weak primary sprout. The tubers produced on a vine are small, and according to the testimony of a grower, reproduce a similar witch's broom.

Potato tubers injured by the rhizomorphic strands of Armillaria mellea have been found for the past two seasons on newly cleared soil planted to potatoes. This trouble is probably more of curiosity than a disease to cause serious loss.

A rotting of potatoes in the field was found to be associated with a Phoma on the stem. The organism was cultured and found to be slightly pathoenic to potato tubers kept under ordinary laboratory conditions. The disease differs from that recently mentioned by Melhus. The causal organisms when grown in comparison cultures were found to be different.

Last season much more than one-half of the potato crop was destroyed by the Late Blight. Data have been collected from potato shippers and observers in nearly every potato county in the State. A conservative estimate would put the money loss at $4,000,000 last year. This money is a total loss, except in so far as it directs attention to the greatly neglected work of potato spraying. The study of the epidemic of 1912 ($2,000,000 loss) and the epidemic of 1915 as related to weather conditions has led to certain correlation with the weather and this is being prepared for publication.

Cercospora concors one of the minor potato leaf-spot fungi, was discovered at Marquette, Michigan, last September.

The discovery of the Powdery Scab at various points in Minnesota gave warrant to the suspicion that the disease was present in Michigan. The county agents in suspected districts were notified, but as yet, no case has been discovered. No thorough survey by a plant pathologist has been made, but the seriousness of the disease well warrants a careful search.

Black Leg of potato continued serious in many fields of the Upper Peninsula. It was found doing much damage late in the season. In one field 25% of the vines were found diseased early in September. The disease progressed in the wet period which followed until 75% of the vines were rotted. Potatoes from the same car which had been carefully sorted in the fall and again in the spring and which were treated with formaldehyde for scab gave a crop which showed less than 1% Black Leg. The soil in these two plantings were similar in kind and neither soil had had potatoes the previous year. The results of these plantings point to poorly sorted potatoes as a source of the trouble, and indicate a dispersion during the growing season.

Black Leg was found in Kalamazoo, Kent, and St. Clair counties last year. It seems safe to say that it occurs only sparingly in the Lower Peninsula. The question is as yet unsettled as to whether the comparative freedom of the lower part of the State as contrasted with the widespread occurrence in the Upper Peninsula is due to climatic differences, or whether it is due to lack of introduction of the parasite. It should be noted that the Black Leg found in Kalamazoo county occurred on seed introduced from the north.

GRAIN DISEASES.

Urocystis occulta, a serious smut of Rye has been found by Dr. Bessey. In one field 5% of the heads were found, by actual count, to be affected. The seriousness of this disease is as yet problematical. There is the possibility of its becoming as great a pest as oat smut. In a rye-growing state like Michigan such an occurrence would be a calamity. This disease illustrates the great need we have of facilities for initiating a vigorous careful survey to determine the seriousness and possibility of spread of such a parasite. Wheat scab was reported in Kalamazoo county as causing from 25% to 50% loss in affected fields.

VEGETABLE DISEASES.

The onion crop last year was cut practically in two by an epidemic of Downy Mildew caused by *Peronospora schleideni*. This disease and neck rot have been found by Mr. Munn of this department to be deciding factors in onion growing. In one storehouse at Wayland, Michigan, 2500 bushels of onions shrank to 1200 bushels due to the ravages of the parasitic Botrytis which causes neck rot. The survey of the onion crop was extremely important because up to date no definite information upon onion disease problems in the State was at hand. The information indicates a field for extension work.

A pecular fruit rot of tomato has been observed at a Grand Rapids greenhouse for a number of years. It manifests itself by a blackening of the fruit, the blackening involving the skin and the tissues. It differs from the ordinary fruit rot in that it usually begins high up on the fruit, not at the calyx end. A yellow bacterial organism has been isolated and its pathogenicity proved. The organism seems to differ from *Bacterium michiganense,* especially in the fact that no wilting of the stem occurs. All evidence points to insects as the carriers of this disease in the greenhouse. Where insect depredations are uncontrolled the loss may be serious. With good control the spread of the disease is slight and the loss negligible.

Septoria lycopersici, the leaf-spot organism, caused a practical failure of the tomato crop in some sections of the State.

Alternaria nigrescens, causing the leaf blight of muskmelon, continued as the serious enemy of muskmelon culture in the State. The crop from muskmelon growing centers was cut practically in two last year. The loss the preceeding year amounted to almost one-fourth of the crop. Michigan melons found no favor in the market due to their poor flavor. This lack of flavor was due to the leaf injury induced by this parasite. Severe attacks almost always occur on land where rotation is not practiced. The common history is that melons do well the first year or two in a new locality, and then begin to fail. A better planned cropping system coupled with timely spraying would undoubtedly save this young but promising industry from this annual loss.

Cucumber diseases continued as serious as formerly. The loss from cucumber scab, caused by *Cladosporium cucumerinum* was found to amount to $1,000,000 in the acreage controlled by one of the large pickling companies.

Bean diseases caused a loss amounting in the aggregate to $2,000,000 last year, wet weather contributing to make the crop only one-half the normal size. The *Phyllosticta phaseoli* disease of cow pea was found in several fields last year. This occasioned some alarm since the lesion was thought by the growers of cow peas to be caused by the bean Anthracnose. The disease no doubt does some damage but does not cause a great loss to the crop.

Black Leg of cabbage was found producing 100% loss in certain fields in Branch county.

Sugar Beet root rot due to *Corticium vagum solani* caused a 25% loss in poorly drained soil. *Cercospora betae* blighted many fields and in general reduced the crop several tons per acre.

Red Clover leaf-spot due to *Macrosporium sarcinaeforme* caused 10% to 15% loss of crop in some fields last year.

MISCELLANEOUS DISEASES.

The White Pine Blister rust which is now known from all the states surrounding Michigan has not yet been found here. The fact that large plantings of white pine have been made in the State, many of which were with imported seedlings, makes the presence of the disease in the State extremely probable. An accurate survey has not as yet been made, but the situation warrants such work. A similar blister rust of Western Pine was reported from Grand Rapids, and on investigation the disease was traced to seedlings obtained from the Roscommon nursery. This disease is probably not serious, due either to the scarcity or lack of commercial value of the hosts.

Marssonina sp. was found defoliating Euonymous in the Botanical Garden. The disease has persisted a number of years but is restricted to the one species although the diseased tree is surrounded by other species of the genus.

A complete killing of the tops of Peony by *Cladosporium paeoniae* was seen at Adrian last year. *Botrytis peoniae* caused the death of many shoots in another plantation of peony in the spring of 1916.

The Septoria leaf spot of Phlox caused failure of many beds of Phlox last year.

Professor E. A. Bessey:

Dear Sir—I have the honor to submit the following report for the fiscal year ending June 30, 1916:

Approximately three-fifths of my time has been devoted to Experiment Station work which has been carried on under the Adams fund. The appropriation for the past year was $500. This sum has been expended for glassware, chemicals, labor,—both common and technical,—and special apparatus, necessary for the working out of the Adams fund problems, a statement of which is as follows: "The absorption of solutes, with special reference to balanced solutions."

Attention has been directed during the past year to a study of the possibility of working out, through the aid of our former studies on the laws governing absorption of water and mineral nutrients, a rational system of soil fertilization on the basis of balanced solutions.

Work in the laboratory and greenhouse has shown: First, that, in the case of water cultures, a three-salt solution is eminently satisfactory for the growth of wheat and peas for at least the first five weeks. These salts are KH_2PO_4, $Ca(NO_3)_2$, and $MgSO_4$. They contain all the essential elements for growth except iron which is added in trace to the solutions. This three-salt solution gives better results than any of the many solutions using four or five different salts, and heretofore considered as suitable for nutrient solutions.

Second, it has been shown that certain proportions of the three salts give better conditions for growth than other proportions. In a series of 36 cultures in which the total concentration remained the same throughout, but the partial concentration of the three salts was divided into ten equal parts, it was found that the 5-3-2 proportion was best ($5KH_2PO_4$—$3Ca(NO_3)_2$—$2MgSO_4$). The second best proportion was 3-

3-4 ($3KH_2PO_4—3Ca(NO_3)_2—4MgSO_4$). This shows that there is a best or optimum proportion of salts, and not as formerly believed that the proportion could vary widely without apparent detriment to the plant.

Still another feature of importance is the total concentration of the solution. Some may have a total concentration too weak to support life and some too strong. A certain concentration is essential, and this concentration determines the proportion of salts best suited for the plant under study.

In applying these findings to soil culture it is readily seen that there will be many conditions less easy to control than in the case of water cultures. Studies have been made and are being continued to determine if possible what total concentration of the three salts and what proportion of salts will give the best growth in pure quartz sand, ordinary sand and soil cultures and what influence adsorption, soil grain size, the presence of chemicals, organic substance and other factors have on this concentration and proportion.

As far as can be learned no other station is carrying on such a problem. Its practical application and its universal value should make this investigation one of importance. The work has so developed, has opened up so many lines of study, besides showing the need of a restudy of certain phases, and has become so large that the need of technical assistance has been felt for the past two years, and especially so the past year. It is suggested therefore, that two half-time graduate assistantships or one full-time assistantship be established, these students or this assistant to devote the time to the study of some phase of the general problem.

Preliminary studies have been made and more extended ones are being instituted to determine if possible what salts and what proportion of salts are needed to improve the soil solution for plant growth. The soil solution is obtained by the pressure method. This work is done in cooperation with Mr. Morgan of the Soil Bacteriological division of the Bacteriological department who is to supply the soil solution. These studies should indicate what to do with "sick" soils from which the soil solution has been pressed.

Other problems are pressing, such as (1) Physiological studies of the effects of poisons on plants with reference to their use in the eradication of Canada thistle, wild mustard, etc., from fields, (2) Nutrition as related to physiological diseases, and (3) the water requirement of plants with special reference to the period of growth in which the most water is necessary, the effect of nutrients on water requirement and the power of the soil to supply moisture to the plant. In regard to this latter phase a simple and efficient method has been devised to study this relation between the soil moisture and the growth of plants in the field. This work was done under my direction by O. E. Harrington as a minor requirement for the M. S. degree. The paper will soon appear in Physiological Researches under the title "Depression of the freezing-point in triturated plant tissues and the magnitude of this depression as related to soil moisture."

The effect of a nutrient solution lacking one element on photosynthesis in corn and cucumber plants has been studied with the result that many interesting facts have been obtained and new lines of investigation opened up. It might be mentioned here, that this study has shown, that the general assumption that the amount of photosynthate made in leaves is an indication of vigor, is far from true. The work was done by O. M. Gruzit as a minor requirement for the M. S. degree. A preliminary report on this work was given at the last meeting of the Michigan Academy of Science. It has seemed advisable to withhold publication for the present until the new phases opened up are more thoroughly studied. Mr. D. A. Seeley has had under investigation as a major requirement for the M. S. degree the problem of "Michigan Climate and Plant Growth."

Owing to an abundance of manuscripts to appear in the American Journal of Botany the publication under the title "The question of the toxicity of distilled water" referred to in my last report was not published until the October number. A paper entitled "A simplified apparatus for measuring the conductivity of electrolytes" in co-authorship with Professor C. W. Chapman of the Physics department, was issued by the Station in November as Technical Bulletin No. 23.

The rest of my time, approximately two-fifths, has been taken up with instructional work both in the undergraduate and graduate departments. With the able assistance of G. R. Johnstone I have had less to do with the laboratory work directly than before. However, the lectures, special problem work in the winter and spring terms, and the general direction of the physiological work has rested on me.

The recommendations of the last two reports in regard to crowded conditions in the Station botanical laboratory the advisability of segregating the two branches of research,—plant physiology and plant pathology,—and the need of additional greenhouse space may be repeated.

Thanking you for another year of generous assistance, helpful advice and loyal support at all times, I am

Very respectfully,
R. P. HIBBARD,
Research Assistant in Plant Physiology.

Dr. E. A. Bessey:

Dear Sir—I submit at your request a report of the work done during the past year. This work was carried on entirely under the State fund of the Experiment Station. A leave of absence was granted me to complete the graduate work for the Masters' degree at the Agricultural College of Cornell University. This leave extended from February 5th to May 5th.

As heretofore, my work has been chiefly upon control measures for the Anthracnose and Blight of beans. We have continued the testing of an early maturing, disease escaping, variety of beans and secured data from various localities of the State regarding its behavior under weather conditions favorable to the disease. The growing of Michigan beans under irrigation conditions in the western states as well as the testing of such seed in this State is being carried on. The value of "clean picked" seed and Anthracnose "resistant" red kidney beans is also being demonstrated. To give these various kinds of seed a thorough test, they are being grown in cooperation with the county agents, growers and bean jobbers in fourteen counties. One acre is planted in each county. On this plat are grown Early Wonder, Idaho-grown Michigan and Clean Picked seed. These experimental plats are located in the following counties: Eaton, Grand Traverse, Gratiot, Genesee, Huron, Ionia, Kent, Livingston, Mecosta, Newaygo, Oceana, Saginaw, Sanilac, and St. Clair. In all there are twenty experimental plats. On the College experimental plats these experiments have been duplicated.

Special stress is being laid upon the investigation of the means of dissemination of the bean Anthracnose and Blight organisms under field conditions.

Seed treatment with chemicals, hot water and dry heat have in the main proved unsatisfactory. In most cases, when the fungicide strong enough to kill the organisms penetrates to the deeply imbedded fungus mycelia or the bacteria, it also kills the bean seed. One chemical employed seems to promise more satisfactory results and further tests are being made with it.

In connection with the graduate work done, during leave of absence, the results show that for the seed treatments employed, there was no effect upon the susceptibility of the plants to disease.

For the past two seasons, a stem disease of beans has caused serious damage to the crop. This disease attacks the stem at the first node, girdling it and causing the plant to fall over. This breaking over is usually seen when the beans are about half mature. This disease is being investigated and inoculation experiments both in the greenhouse and field have been started.

Some work has been done with a leaf-spot disease of greenhouse geraniums. This leaf spot seems to be of common occurrence. The causal organism, a species of Pleospora, has been isolated and its pathogenicity established. Cross inoculations with species of Ascochyta from Vetch, White Sweet Clover and Pea are being carried on preliminary to a more thorough study of these diseases.

Very respectfully,
J. H. MUNCIE,
Assistant in Plant Pathology.

REPORT OF THE CHEMIST.

Director R. S. Shaw, East Lansing, Mich.:

Dear Sir—I herewith submit a report of the Chemical division for the year ending June 30, 1916.

The work of the Division is now sharply divided between the control or inspection work and the research problems being carried on under the Adams and Hatch funds. Owing to the immense amount of detail involved in the inspection work the writer has been obliged to turn over to Mr. Robinson, the supervision of all the problems under the Adams fund and his review of the year's work is made a part of this report.

Mr. O. B. Winter, who formerly has been connected with the inspection work was advanced to the position of Research Chemist and now devotes his entire time to problems under the Hatch and Adams projects. Mr. Ove Jensen resigned September 1st, 1915, to take up advanced studies at the Iowa Agricultural College.

The following appointments have been made during the year:

E. F. Berger, Sept. 1, 1915, Assistant Chemist.
E. J. Miller, Sept. 1, 1915, Assistant Chemist.
A. E. Smoll, Jan. 1, 1916, Assistant Chemist.
Wells Sizer, Jan. 1, 1916, Inspector.
F. F. Hebard, Feb. 1, 1916, Inspector.
C. F. Barnum, Feb. 10, 1916, Inspector.
C. R. Cady, March 1, 1916, Inspector.

Mr. Sizer resigned April 1st and Mr. Cady on May 1st.

CONTROL WORK.

Fertilizer inspection: During the year 303 brands of fertilizer were licensed for sale and 358 different samples were analyzed. A fall collection was made for the first time which resulted in our finding a number of unlicensed brands being offered for sale. On account of this extra work the publication of the annual fertilizer bulletin was delayed until after January 1st. The result of the fall collection justifies the expense involved and in the future this plan will be followed.

In December, 1915, The Mineral Fertilizer Co., Chicago, Illinois, applied for a license to sell their Nu-Life Fertilizer in the State. They complied with all the requirements of the law and a license was accordingly issued to them. No shipments were made until early spring, when several cars were sent into the State and a whirlwind campaign was inaugurated to dispose of them among the farmers at $30.00 per ton. It was advertised to be basic-slag and to possess wonderful fertilizer properties. Upon analysis, however, we found it to be a mixture of rock phosphate and a material which resembles, both in appearance and chemical composition, the slag from an open hearth iron furnace. Further, our examination shows that 85% of the phosphoric acid contained in the mixture is derived from the rock phosphate. By personal correspondence with a number of dealers the sales were quickly checked and probably very little has actually been sold.

This experience reveals a weak point in the fertilizer law, in that it allows the administrative officer no discretion in the issuance of licenses. Any manufacturer or dealer wishing to sell a material as a fertilizer, by filing the required copy of the analysis and certificate together with a sample of the article, is entitled to receive a license upon payment of the fee. Furthermore, no authority is given for revoking a license when it is proved that the material being sold is purely a fraud. Under the present condition publicity through the press and personal correspondence is our only recourse, since if we wait for the publication of the bulletin the information reaches the farmer too late.

In order to meet such conditions, the law should be revised, if possible, at the next session of the legislature.

Insecticide inspection: A bulletin giving results of the inspection of insecticide and fungicide samples collected during the spring of 1915 was published during the year. A collection of samples has been made during the past few weeks and the analytical work will be started at once. Some infractions of the law have been found but in most instances it has been wholly through ignorance of its provisions.

Feeding Stuffs Inspection: At the last session of the legislature the Administration of the Feeding Stuffs law was transferred from the Dairy and Food Commissioner to the State Board of Agriculture and this office was placed in control of the work. The law effecting the change became operative the latter part of August, 1915, but as no funds were transferred nothing could be done until a sufficient amount had been accumulated from the issuance of licenses. The collection of samples was begun the first of January, and by temporarily employing extra inspectors the whole State was covered in about four months and nearly 1200 samples were collected. The analytical work is now about completed and it is hoped to have the bulletin ready for publication before the fall collection begins.

By a cooperative arrangement with the U. S. Department of Agriculture the writer was appointed a commissioned State official, under the Federal pure food and drugs act, with authority to collect samples of feed from interstate shipments and refer the same to the Federal inspection laboratory at Chicago. This authority was also vested in our inspectors and 31 samples of low grade cottonseed meal were referred to the Federal authorities for action against the original shippers.

Objection was raised by the State millers in regard to our ruling requiring a license on Wheat Bran with ground screenings not exceeding mill run and Wheat Middlings with ground screenings not exceeding mill run. The law states plainly that wheat bran and middlings when unmixed with other materials are exempt. The millers claim that it is impossible to clean the wheat of all foreign material and that the bran and middlings will always contain some screenings. We contend, however, that the amount of screenings left in the wheat as it goes to the rolls, under modern milling processes, is necessarily very small, and consequently the amount of screenings occurring in the bran or middlings should never be more than one or two per cent. Such an amount would be negligible.

Examination of a large number of samples of both bran and middlings showed the amount of screenings to vary from less than 1% to 30% with the majority of the samples containing over 2 per cent.

It is our opinion that the presence of screenings in either bran or middlings in excess of 2 per cent is an indication that the screenings were first separated from the wheat and later mixed with the bran or middlings. Such a practice is a form of adulteration and the products so prepared should be classed as mixed feeds, and, as such, be subject to the provisions of the law. The large millers of the Northwest and other states have, in no instance, taken exception to our ruling on this point. The Attorney General has also supported our ruling in an opinion handed down on this point.

In several instances the exact meaning of the law is not clear, especially in Section 2 which defines the term concentrated commercial feeding stuffs. The law should be amended at the next session of the legislature.

HATCH FUND.

The study of the factors causing disintegration of cement drain tile has been finished and the results have been published as Special Bulletin No. 75. Some further work has been done during the year on certain phases in connection with the manufacture of impervious tile. The investigation has now brought to a close.

Definite results are looked for this year, from fertilizer experiment being conducted in conjunction with the Horticultural division, in the orchard of J. E. Merritt, Manistee, Michigan. The experiment was first started in the peach orchard in the spring of 1914 and the trees should bear a good crop of fruit this year. The writer visited the orchard October 1st, 1915, and took careful measurements of all the trees in each plot and those fertilized with nitrate of soda averaged 1.5 inches larger in circumference one foot above ground and 12 inches taller than those not receiving nitrate of soda. Phosphoric acid and potash have apparently been of no influence as far as growth of the tree is concerned. The effect of the fertilizer treatment has not been so apparent where applied to cherries and apples.

ADAMS FUND.

The addition of the services of two men, Mr. O. B. Winter and Mr. E. J. Miller, to those formerly engaged in work on Adams fund projects has made possible the accomplishment of a great deal during the past year.

One stage of Project 2b, "Adsorption in Relation to Soluble Fertilizer Salts" has been completed and the manuscript is now undergoing final revision before being presented for publication. The work described in it is a continuation of that reported in Technical Bulletin No. 19. It constitutes a valuable addition to our knowledge of the nature of soil acidity and the effect of applying various soluble fertilizer materials to soils.

The work under Adams 2ba, "The Organic Nitrogenous Compounds of Peat Soils" has been continued as outlined in the last report. More work than was originally planned has been done on the quantitative study of the various forms of nitrogen in peat and the publication of the results has been delayed thereby. The work has been finished, however, and the manuscript is being prepared.

The extension to other organic materials of the method of studying the nitrogen compounds of peat has been started and data has been obtained on the composition of the organic base goods used in the manufacture of fertilizers.

The first series of experiments on the study of the composition of the drainage waters from soils treated with various materials has been completed and the manuscript is in course of preparation. New work has been started along this line to determine the effect of liming peat and muck soils.

A manuscript describing the preliminary work on Adams 2e, "Adsorption in Relation to Osmosis in Soils" is nearly complete. The work under this project has shown that so called osmosis is a complicated process and that it may be of considerable importance as a factor in soil fertility.

MISCELLANEOUS.

One hundred and seven samples of a miscellaneous nature have been analyzed during the year, and in addition, a large number of marl and limestone samples have been examined as to their value for applying to acid soils.

As referee on the subject of Inorganic Plant Constituents for the Association of Official Agricultural Chemists the writer has done considerable work on methods of analysis and other members of the staff have collaborated on methods of analysis along other lines.

The usual course of lectures on Fertilizers was given to the short-course students in Horticulture and General Agriculture.

Respectfully submitted,
ANDREW J. PATTEN,
Chemist.

East Lansing, Mich., June 30, 1916.

REPORT OF THE ENTOMOLOGIST.

Director R. S. Shaw:

Dear Sir—Following is a brief report of the work of the Division of Entomology for the year ending June 30, 1916.

The year was made notable by the most serious invasions ever known to the writer, of two insects, viz., the bean-maggot, and the red cherry leaf-beetle. The former insect was studied and a bulletin was presented by Mr. Don B. Whelan, to whom this pest was assigned. Mr. Whelan succeeded in finding out the conditions under which this pest thrives and the methods of avoiding its attacks. The whole matter is discussed in Circular No. 28.

The work of rearing the parasites of the San Jose Scale has progressed somewhat, several additional species of parasites having been added to the list already on hand. There is also evidence that the work of these parasites in some restricted area has been effective enough to be distinctly felt, although not sufficient to warrant even considering a change in our spraying policy.

Our attempts to introduce the European parasite of the Tamarack Saw-fly have apparently failed and the attempt is to be discontinued until we are able to secure more material from Europe.

An attempt to locate the cause of injury to peaches in southwestern Michigan led to some measure of success, although much remains to be done in devising means to control the pest.

A new project was started in the spring to determine the comparative insulating values of several of the more commonly employed substances as fillers in double walled bee-hives. These substances are being tested by Mr. G. C. Woodin in comparison with dead air spaces and with each other, at the request of some of those interested in the manufacture of bee-keepers supplies.

Dr. G. D. Shafer, with the publication of Technical Bulletin No. 21 on "How Insecticides Kill," has discontinued active work on that project, (4b) and has started work on project (4c), a study of the factors which govern mating in the honey-bee. The preliminary work on this project is progressing favorably.

Many insect pests have been received and reared in the course of the year.

Respectfully submitted,
R. H. PETTIT,
Entomologist of Experiment Station.

East Lansing, Mich., June 30, 1916.

REPORT OF THE HORTICULTURIST.

Director R. S. Shaw:

Dear Sir—I herewith submit the report of the work in Horticulture for the year ending June 30, 1916.

Much of the horticultural work has consisted of a continuation of the experiments referred to in previous reports although this work has been considerably increased due to the addition of another member to the Experiment Station force during the past year. Mr. H. J. Bock was employed January 1, 1916, as an experimental assistant in horticulture to work particularly on the subject of bud variation and selection and has also undertaken other lines of experimental work in pomology.

Of the experiments previously reported, those upon spraying have been considerably enlarged upon due particularly to increased facilities for performing these experiments and to the increased demand for work along these lines. At the present time, in addition to the spraying experiments on fruits and potatoes that are being carried on at this place, we are making rather extensive spraying experiments with the various dust sprays now being recommended by some commercial concerns, particularly at the Strange orchard at Grand Ledge and at George

Winegar's orchard at Morrice. Many commercially prepared sprays are now being offered on the markets for use by our fruit growers and we find it necessary to test these before recommending them as desirable sprays to use. The increased cost of spraying materials due to the present abnormal condition of the market for many of these has also made it necessary for us to ascertain how weak many of these sprays may be applied to prove efficient while in former years it was rather a question of how strong they could be used without injuring the fruit or the foliage.

Our experiments along the lines of commercial fertilizers for tree fruits, thinning apples and freezing experiments on fruits are being continued as outlined in previous reports.

In addition to these, we have started some very important experiments along the line of critical temperature studies on the various fruits during their development in the spring, starting just before the blossoming period when fruits are susceptible to slight freezes and following through this dangerous period of their development until after danger of spring frosts has past. These experiments, we hoped to correlate with some outdoor tests in orchard heating but unfortunately, no severe frosts occurred during this period the past spring.

With the wonderful collection of varieties of fruits available at our South Haven Experiment grounds, we are now beginning to make studies on the inherent characters of these varieties in crosses. Mr. Bock has been engaged in making crosses of all the fruits during their flowering periods and seeds of these crosses will be saved for future work. After these characters of our standard varieties have been ascertained, we will have a foundation for intelligent work in improving by crossing our present standard varieties.

On the farm of Mr. George Low at Bangor, Michigan, we have made a number of grafts on Concord grapes with the important commercial varieties of Vinifera grapes such as are at present grown in California. It is our plan to protect these vines during the winter by burying the canes in the soil. If such varieties can be grown successfully and protected economically, it will prove a great addition to the fruit industry of this State.

Records have been obtained for two seasons on the bearing habits of Spy trees in the orchard of Luther Hall, of Ionia, and of Baldwin trees in the orchard of B. F. Hall of Belding. This work is being carried on in cooperation with the Office of Pomological Investigations at Washington. Records are kept of each tree as to size, yield and peculiarities of the fruit. This work we are continuing and hope also to carry on with grapes and other fruits.

Records have also been kept of carnation plants and cuttings of several standard varieties have been gathered from the various florists in this State to determine if there is any benefit in taking cuttings for propagation from plants which have borne a large number of good quality flowers. We hope to enlarge upon our experiments with greenhouse crops in the near future when our new greenhouses are erected.

Respectfully submitted,
C. P. HALLIGAN,
Acting Horticulturist.

East Lansing, June 30, 1916.

REPORT OF THE SOUTH HAVEN SUB-STATION.

Professor C. P. Halligan:

I submit this report of the South Haven Sub-Station for the year ending June 30, 1916:

A considerable increase in experimental work has been planned and is being carried on this year. Plant breeding and spraying experiments constitute the bulk of our endeavor and it is hoped to continue along this line of work for a series of years.

H. J. Bock of the Experiment Station staff has spent considerable time this spring cross pollinating fruits included in our collection. It is always possible to improve those varieties now in favor and to attempt to secure new sorts that may prove to be commercially important. His work includes the crossing of peaches, cherries, plums, apples and grapes.

He has also conducted critical temperature experiments with fruits in their various stages of growth. By subjecting these fruits to different freezing temperatures in their various stages of growth, information is gained upon their susceptibility to low temperatures.

W. F. Wight of the Bureau of Plant Industry, recognizing the value of our collection of pears, has made extensive crosses with them this spring. Possessing the foresight from considerable experience in this work, very interesting and valuable results are anticipated. He has introduced pollen from pears that he has developed that possess, to a remarkable degree, many desirable characteristics.

Our spraying experiments started this year, include investigations on controlling San Jose scale, diseases of plums, peaches and grapes and the codling moth of apples and pears. In this work, some of the newer commercial spray mixtures are being used in comparison with those now generally accepted to be the most suited for average conditions.

In general, fruit conditions and prospects are about normal, though some reports have been received that cherries especially did not set well, cutting down the crop promised at blooming time. To some extent, plums have suffered in like manner. This has been especially true in our own orchards. Numerous cherry and plum trees that bloomed profusely did not set one-third of a crop and in some cases even a lower percent of a crop.

Peach leaf curl seems very prevalent this spring on most all susceptible varieties and in some instances has developed very extensively. Investigation indicates that the trouble has been due, in a great measure, either to a failure to spray at all or to apply the mixture at the proper time. Growers that make a business of proper spraying state that unfavorable weather conditions seriously hindered spraying at the proper time. On trees that were sprayed at the proper time, leaf curl is less evident than those that received the application a little late. It seems quite evident that the cold, wet spring has been very favorable to the development of this fungus.

The aphis situation is quite favorable at the present time. Growers have been more efficient in controlling this insect and in most cases, very good results have been reported by including the contact spray for aphids in the scale preparation. Later applications for this insect have not been so successful and only in a few cases, necesary. It is quite possible that aphis parasites have increased in sufficient numbers to render their aid in its control.

Our equipment needs many additions without which best results cannot be secured. The buildings are badly in need of repair; a small laboratory and greenhouse would be valuable additions and would increase our field of experimental work.

Respectfully submitted,
I. R. NOTEWARE,
Superintendent.

South Haven, June 30, 1916.

REPORT OF DIVISION OF FARM CROPS.

Director R. S. Shaw:

Dear Sir—I have the honor to submit the following report for the Division of Farm Crops for the year ending June 30, 1916:

The testing of varieties of corn has been continued as heretofore, and data accumulated from this experiment and the cooperative corn tests about the State are of value in determining the choice and adaptation of different varieties to different sections of the State. It is planned to publish the results of this experiment before another planting season. In addition to the value of this work as an Experiment Station project, it has been of much value as a means of furnishing material for our students in the study of types, adaptation, variation, maturity, etc., of corn.

The rotation, fertilizer and manure experiments have now been in progress for five years, the more important data secured being given in the following tables:

TABLE I.—*Results of Application of Fertilizer to Wheat in Corn, Wheat, Clover Rotation, 1911-15*

Treatment per acre.	Average yield wheat (3 crops) after fertilized.	Average yield clover (3 crops) after fertilized wheat.	Average yield corn (3 crops) second year after fertilized wheat.	Value of increase per rotation.	Cost of treatment.	Net value of increase per rotation.
No fertilizer................	21.38	1.61	38.8	....	....	....
75 lbs nitrate of soda..... 200 lbs. acid phosphate.... 75 lbs. muriate of potash..	34.28	2.03	43.7	$19 24	$5 73	$13 51
75 lbs. nitrate of soda..... 200 lbs. acid phosphate....	29.96	1.95	40.1	12 03	3 85	8 18
200 lbs. acid phosphate.... 75 lbs. muriate of potash..	31.68	2.03	42.8	16 27	3 48	12 79
200 lbs. acid phosphate......	27.68	1.98	40.0	10 21	1 60	8 61
100 lbs. acid phosphate.... 100 lbs. floats............	25.56	1.83	40.0	6 80	1 25	4 55
200 lbs. floats..............	25.06	1.88	40.0	6 85	90	5 95

In compiling these data none of the yields of individual plats were assumed to be in excess of those from other plats receiving the same and additional fertilizer ingredients.

TABLE II.—*Results of Application of Manure and Fertilizer to Corn in a Corn, Wheat, Clover Rotation, 1911-15.*

Treatment per acre.	Average yield of corn (4 seasons) after manure.	Average yield of wheat (4 seasons) first year after manured corn.	*Net value of manure per ton.
No manure or fertilizer	41.7	20.7	....
5 tons yard manure	53.1	26.7	$2 68
5 tons stall manure	55.6	27.4	3.15
5 tons stall manure and 200 lbs. acid phosphate	61.7	41.7	6 26
5 tons stall manure and 200 lbs. floats	60.2	31.0	4.26
10 tons stall manure	66.5	38.0	3 29

*Figured from the increase in yields of corn and wheat only. The natural differences in the soil have to a certain extent entered into the yields of clover and these are not included in the above data. It may be said, however, that the average yield from all the manured plats has been .56 tons above the unmanured plats which would add about $1 per ton to the value of the manure.

TABLE III.—*Results of Top Dressing and Plowing Under Manure for Wheat.*

Treatment.	Average yield of wheat (5 seasons) after manure.	Average yield of clover (3 seasons) after manured wheat.	Average yield of corn (3 seasons) second year after manured wheat.	Value of manure per ton.
No manure	25.2	1.39	38.6	....
Top dressing	38.4	2.67	42.9	$5 54
Manure turned under	41.7	2.51	45.3	6 15

TABLE IV.—*Average yield and value of crops grown in rotation, 1911-1915.*

Rotation.	Average yield per acre. Grain in bushels. Beets and hay in tons.			Average annual value of crops.
	Corn.	Small grain.	Hay.	
Corn, oats, clover	38.4	46.7	1.26	$19 39
Corn, rye, clover	41.5	27.1	1.47	21 36
Corn, wheat clover	39.8	25.2	1.39	21 48
Corn, wheat, timothy	37.5	22.6	1.41	20 23
	Beans.			
Beans, wheat, clover	15.6	28.5	1.26	21 85
Beans, oats, clover	12.7	42.3	1.40	17 72
	Potatoes.			
Potatoes, wheat, clover	127.2	31.2	1.36	35 09
	Beets.			
Beets, oats, clover	5.21	46.0	1.76	20 68
	Corn.	Beans.	Soy beans.	
Corn, beans, clover or soy beans	34.6	12.0	11.0	23 32
Beans continuously	....	11.6	....	20 30
		Wheat.		
Wheat continuously	....	23.2	....	20 88
Corn continuously	36.2	....	....	25 34
	Beets.			
Beets continuously	5.9	....	....	29 50
	Potatoes.			
Potatoes continuously	93.2	....	....	46 60
Timothy continuously	....	....	1.16	11 60
Alfalfa continuously	....	....	2.31	23 10

In the application of commercial fertilizer to wheat in the corn, wheat, clover rotation (Table I) the largest yields and the largest net value of increase have been secured from the application of the complete fertilizer. In this case an investment of $5.73 in fertilizer resulted in a crop increase value at $19.24 and a net profit of $13.51. The use of acid phosphate and muriate of potash have given nearly as much profit, viz., $12.75. On the farm to which more or less manure is applied this treatment would probably show a greater relative profit. The use of the acid phosphate alone has given a slightly larger net profit than the use of nitrate of soda and acid phosphate. The acid phosphate has produced better results than the floats or raw phosphate, although the latter have shown a good profit.

It is of interest to note (Table II) the large increases in the yield of corn and wheat by the use of the manure and the high values placed on manures based on the increases in the two crops only. These values are very much above those usually placed by farmers on their stock manures and indicate strongly, as do also the relative values of the yard and stall manures, the importance of conserving the manure produced on the farm. The stock manure is not, however, a well rounded manure as it contains a relatively small amount of phosphoric acid. When this deficiency is corrected by the use of two hundred pounds per acre of acid phosphate the increase has been sufficient to pay the cost of the fertilizer and nearly double the value of the manure. Michigan farmers have generally paid little if any attention to this point. If the practice of reinforcing manure with phosphate should be generally adopted, it would no doubt result in materially increasing crop yields of the State.

In Table IV are given the average yields and the average annual values of various crops grown in rotation. Many valuable lessons may doubtless be drawn from this part of the experiment, especially after the experiment has been carried on for a few more years and statistics on the cost of producing the various crops have been obtained. The average yields of crops grown continuously on the same plats include those grown the first one or two years of the experiment, which were fairly large. In the last few years the yields on plats devoted to continuous culture of the same crops have come to a very low average, in some cases being far below the cost of production. Difficulty has been experienced in securing a stand of beets on the plat devoted continuously to this crop, many of the beets dying after germination.

This experiment is now in its its sixth year, which will complete the second round of the rotation. This is a favorable time to consider the results in view of any possible changes that may seem necessary in carrying out this experiment. The difference in natural fertility in some of the plats has been a disturbing factor in the experiment. However, by use of the check plats and the triplication of the plats this factor has been largely overcome. It is believed on account of the residual effect of the manure and fertilizer these treatments will win out even against the natural differences that exist in plats.

More irregularity has been manifested in the yields of clover than in the other crops and this may be attributed in a large degree to the lack of lime. In 1912 ground limestone was applied at the rate of two tons per acre on the north half of all the plats in two of the series. Little effect of this treatment could be observed in 1912, '13 and '14, but in 1915 a rather marked effect was noticeable in the clover and the same condition may be observed in the 1916 crop. The clover on the limed portion of the plat has been of a much larger, thicker and more even growth and more free from weeds, especially sorrel. The difference between the limed and unlimed portions has been more marked on the fertilized plats than on the unfertilized and less marked on the manured than on the unmanured. It is planned to make a fairly liberal application of lime, with the possible exception of one or two plats in each series as a check on this point. Additional tile drainage is also required on some of the plats.

This experiment was planned mainly for the purpose of determining the best rotations and the best farm practices in regard to use of manures and fertilizers. However, on the average farm some manure or other organic matter is returned to the soil while in many of these plats nothing has been returned and doubtless on account of this some of the crop yields have not been as large as we would desire. It may be best to make such an application of manure to the rotation plats occasionally as would return the organic matter removed by the crop and approach as near as possible to general farm conditions. Other members of the Station Council will be consulted in regard to this matter and I shall endeavor to arrive at some plan, if thought best to make any change, that may be put in operation in 1917 and may be followed indefinitely.

It is also planned to extend this experiment to include some fertilizer and manure work with beans and sugar beets. These two crops are more or less distinctive in Michigan agriculture and are cash crops which usually give good returns from the use of fertilizer, but in regard to fertilization of which we have very little experimental data.

Plans are also being made for starting other lines of investigation which will be of value to Michigan agriculture.

Mr. Eugene E. Down has been appointed as Station Foreman and Station Assistant in Farm Crops, taking charge of his work April 1, 1916.

The crop improvement work of the division has been under the able direction of Mr. Frank A. Spragg. The appended report which he has made to me should be included as a portion of the report from this Division.

Respectfully submitted,
V. M. SHOESMITH,
Farm Crops Experimentalist.

East Lansing, Mich., June 30, 1916.

REPORT OF CROPS BREEDER.

Professor V. M. Shoesmith:

Dear Sir—The crop improvement work of the year has continued the older lines of work that were not complete, and undertaken as much new work as the resources at hand would permit.

The season of 1915 was exceptionally wet and with it came new problems. The difficulties of harvesting detained operations and the winter crops were not planted in time. The small growth that the wheats made last fall, coupled with the open winter that at times allowed the plants to grow before freezing up again, has resulted in extensive winter killing. Thus, the winter has proven to be nearly as severe as the cold winter of 1911-12, with the same beneficial results, i. e., a new variety of wheat is attracting considerable attention because it is outstandingly vigorous. It is a strain originating in an individual plant that stood the winter of 1911-12 in good shape. This new strain (No. 28206) is awnless as well as a red wheat, but as to quality the Experiment Station has no further data. This is the first year that a milling test has been made with this wheat and the baking test has not yet been made.

Certain of the extractions from wheat crosses made in 1912 are attracting considerable attention in the row series. This is particularly true of those that come from the cross between Berkley (03402) and

Red Rock (97003). The Berkley is the best milling and baking variety of hard winter wheat that this investigation has been able to find (1912), but because of the weakness of its straw is not a commercial success in Michigan. The Red Rock attracted our attention in the spring of 1912 as being the only stiff strawed wheat that had stood the previous winter in good shape. Both of these varieties being hardy, a cross between them may be expected to be hardy, and the hope now is that we have a stiff strawed wheat that possesses the high milling and baking qualities of Berkley. Such a wheat would bring a new epoch in Michigan wheat growing, as the miller could then have Michigan grown hard winter wheats to grind, and there would be no further need for the importation of western grown hard wheats.

A series of new wheat-crosses has been lately made between the outstandingly attractive wheat (No. 28206) and the most promising bearded wheats of the series so that should the present row series fail to yield the desired combination of qualities, a new trial would be under way.

Two bulletins have recently been written on winter crops, hoping that they may be in the hands of farmers before September 1. One of these is on Red Rock wheat, the only hardy high yielding red wheat that has been introduced among the farmers. The other is on Winter barley, the new winter crop that has yielded from 152 per cent to 174 per cent of Oderbrucker whenever the Winter barley has been planted early enough to cover the ground before winter set in. It is clear though that this new crop must be planted by September 1st if it is to succeed in making high yields. Under these conditions the tops of the Winter barley usually freeze down so completely as to kill nearly all of the Hessian fly that may have been formed on the stems.

Among the spring crops the bean improvement work is being pushed more extensively than ever. During earlier years, the large number of oats and barley selection plats gave little opportunity for the bean selection work.

The work with beans began in 1908 with individual plant selection from commercial lots. It was continued in a small way until these early selections had been tested out in variety series along with local farmers' varieties from over Michigan. As a result a strain of Navy (No. 81302) beans (now known as the Robust) was discovered that on an average of three years yielded 150 per cent of the best commercial variety that had been found. The result was so conclusive that no variety series was considered valuable in 1915, giving opportunity for more extensive indivdual plant work. The Robust had never been standardized from the standpoint of shape and size.

Need was discovered for investigation into the inheritance of shape and size in beans. Some bean crosses that had been obtained in 1912 and 1913 gave extensive segregation of shape and size. This material was taken over by Mr. P. K. Fu in the fall of 1914, and he undertook the investigation of this problem in 1915 as a Master's thesis. From among the 1914 individual plant selections, about 200 were chosen to become mothers of individual progeny plats in 1915. These lots totaled 14,280 seeds from which 10,787 plants were obtained. The cold, rainy weather of August stimulated vegetative growth and the setting of new flowers too late to ripen before the early frosts. Thus came the failure of nearly all that would yield data on the inheritance of shape in beans. Four thousand five hundred and ninety-two plants were threshed individually and the seed placed in envelopes. The data gave very good evidence on the inheritance of size. The majority of these data shows Mendelian segregations of one pair of characters, the large size being dominant. The segregations of greater complexity contained too few individuals to permit of interpretation.

The problem of inheritance of shape is being undertaken by Mr. W. K. S. Sie during the season of 1916. There are nearly 300 progeny plats planted this year, and 157 of these belong to Mr. Sie's thesis work. A small variety series has been planted, and 35 new lots are growing in selection plats. Including increases, the bean work for 1916 aggregates 343 separate plats.

The work with field peas began in 1913 with 73 lots (all mixtures) of which 70 bore U. S. Seed and Plant Introduction numbers. These were planted in a row series using a Michigan sort as a check. As the larger portion of these were foreign, it was thought best to continue all the lots in the 1914 series regardless of their 1913 production. Those that produced poorly both years were dropped from the 1915 plantings. Individual plant selections were made in 1915 and planted in 1916 as progenies.

The alfalfa breeding work started in 1906 when Mr. M. Craig gathered seed from a number of individual plants at M. A. C. Other lots have been obtained yearly from seedsmen, other plant breeders, and through the U. S. Department of Agriculture and from around the world, aggregating 195 sources of seed. Nurseries have been set out in 1907, 1909, 1911, 1913 and 1916.

The first three nurseries contained so much unproductive unhardy material that it was difficult to get progeny plats in a rigid competative test. There were those that winter killed and then others that succumbed in the summer to various diseases resembling crown rots. Yet with each succeeding generation of the breeding work there has been a lower death rate among the plants. In the first nursery very few plants produced seed, but seeding has been more general among the individuals of later generations. The highest yielder of the 1909 nursery produced 41.3 grams in 1910. In the next generation (1911 nursery) there were 30 that exceeded this production in 1913. None of these plants (1911 nursery) produced mentionable quantities of seed in 1914.

The problem now (since we have found hardy alfalfa) is not to get good seed production in favorable years, but to find a strain that will pay its way in the off year, if we are to make alfalfa seed production a success in Michigan.

In 1914, certain individual plants (that were found scattered through the 1913 alfalfa nursery but confined entirely to it), did something that had not been observed in alfalfa before. The nurseries lost their leaves from leaf-spot that year, and the above mentioned plants actually set leaves back on the old stems, stuck to their job, and produced seed that year. Seventeen of them yielded at a rate that would amount to three bushels of seed per acre if such a plant could be found on each space, equal to that occupied by the plants in question. Other plants in the same progenies had this power to a lesser degree. The normal thing for an old-line alfalfa plant to do, when it looses its leaves from any cause, is to give up those stems and start new ones from the roots. The best plant from the best progeny produced 12.8 grams of seed in 1914. This plant has become the mother of the checks in the 1916 nursery.

Investigation into ways and means of eliminating environmental influences upon the data of variety series and nurseries has been vigorously continued throughout the year. The coefficient of yield was mentioned in last year's report. The extension of this method to nursery work has been especially considered during the past year. The problem at hand is the 1913 alfalfa nursery where the checks were planted from one progeny, and the other rows from the best material available and coming from other lines of alfalfa. Some of these progenies represented the fifth generation of the work at this Station.

The figures connected with this investigation would take several pages to report, but it is evident that the environmental factors can be practically eliminated from statistical constants by the application of the method of the coefficient of yield to statistical data.

Respectfully submitted,
FRANK A. SPRAGG,
Research Assistant in Plant Breeding.

East Lansing, Mich., June 30, 1916.

REPORT OF SOIL PHYSICIST.

Director R. S. Shaw:

Dear Sir—I am submitting herewith the report of the Soils division for the fiscal year ending June 30, 1916:

It is indeed gratifying to be able to report progress in the various departmental activities, namely, College, Extension, and Experiment Station.

The members of the department have been very active in Station work and the results obtained are highly satisfactory. As I previously outlined to you, the policy is a problem for every one. To be sure, the problems are to be practical, that is, suited to the training and attitude of the men to whom they are assigned. We should not be led away from this extremely important and far-reaching phase of the College work; if so, unquestionably, we will soon be going in a circle with respect to both College and Extension activitise.

Extensive field projects were gotten under way on the Van Buren county Farm and the Grand Rapids City Farm, the detailed plans of which are now on file in your office. We are positive that here lie exceedingly great opportunities for doing much constructive and economically important work, and that strenuous efforts should be made to establish a limited number of these each year. These projects need not necessarily be confined to the counties provided with county agents, but should be taken up wherever practicable in other counties. Moreover, provision should be made, in the way of assistants, for effectively carrying on this important line of work.

Project No. 1, outlined in last year's report, is being continued. Studies of representative soils of Wexford, Allegan, and Ingham counties have been completed and reports covering these will be presented at an early date. Cooperative lime and fertilizer studies are being conducted with a few farmers of Ingham county. It is well to note that some very striking results are being obtained in certain cases. We recently took samples from, and made observations in, St. Joseph, Cass, and Manistee counties, and plan to do so for certain other counties. We propose to pursue this work vigorously, inasmuch as we consider it a very important and far reaching line of investigation.

The Lysimeter studies, also noted in last year's report, are under way and certain important data have been obtained, especially from those filled with sandy soil. With this particular soil low in vegetable matter and this season's rainfall, the addition of lime alone, or complete fertilizer, or inorganic nitrogen, have shown negative results with oats and clover. On the other hand, unusually good returns have been received from the use of green manure, even in the absence of either lime or complete fertilizer. These results suggest among others that there is very little benefit to be derived from the use of inorganic nitrogen during a season of high rainfall on sandy soils low in vegetable matter. This being a very important economic question, field plots on the same soil have recently been installed to throw additional light upon it.

As outlined in detail in your office, elaborate green manure and lime experiments are being conducted on the Woodbury Farm. Such questions as the cost of nitrogen in green manures, and the duration of green manuring crops, as well as effects upon the chemico-physico-biological properties of the soil are being studied.

Very interesting and especially fundamental results are being obtained from studies of the effect of the presence of different amounts of water, of the addition of green manure and fertilizers, upon the concentration of the soil solution and the sap of roots and tops of different plants. The results of these studies will be presented in due time for publication.

The projects being conducted under the Adams fund have been successfully carried on during the year. The nature of the work has been entirely changed and may be divided under two main headings: (1) Soil Temperature, (2) The Freezing Point of Soils. A part of the report presented to me by Dr. Bouyoucos appears below:

"The results of the second main project appear to be especially of great importance and high interest, both from the practical and theoretical standpoint. These results have opened up an entirely new line of research and have thrown new light upon the behavior and properties of soils. The freezing point method, as has now been developed, appears to be the best means of studying certain phases of the soils, as it attacks the problems directly, and the results it attains are fundamental.

Four different technical bulletins and two short articles have been issued during the year upon the two projects. The titles of the bulletins are as follows: (1) Effect of Temperature Upon Some of the Most Important Physical Processes in the Soil, (2) The Freezing Point Method as a New Means of Measuring the Concentration of the Soil Solution Directly in the Soil, (3) Soil Temperature, and (4) The Freezing Point

Method as a New Means of Determining the Nature of Acidity and Lime Requirement of Soils. The titles of the two articles are as follows: (1) Determining the Concentration of the Plant Cell Sap Directly in the Plant Tissue (in the Journal of the American Society of Agronomy), and (2) Studying Biological Activities Directly in the soil by Means of the Freezing Point Method (in Science).

The investigation on soil temperature is discontinued, at least for the present, and the entire time and all the efforts are concentrated on the freezing point methods and its relation of subjects."

As you know, from discussions, and can judge from this report, we are laying a foundation for a strong and broad Department of Soils. I desire to state that we appreciate greatly your support and advice with respect to several problems that have arisen during the past year.

Respectfully submitted,
M. M. McCOOL,
Soil Physicist.

East Lansing, Mich., June 30, 1916.

BULLETINS

OF THE

Agricultural College Experiment Station

ISSUED DURING THE

YEAR ENDING JUNE 30, 1916.

FERTILIZER ANALYSES.

Bulletin No. 275.

ANDREW J. PATTEN, O. B. WINTER, O. F. JENSEN AND E. F. BERGER.

The inspection and analyses of commercial fertilizers offered for sale in Michigan are made under authority of an act of the Legislature approved March 10th, 1885, and as amended during the session of the Legislature for the year 1913. The principal points in the law of interest to manufacturer, dealer and consumer may be summarized as follows:

MANUFACTURER.

Materials subject to license. The term "commercial fertilizer" shall be held to include any and every substance, imported, manufactured, prepared or sold for fertilizing or manurial purposes, the retail price of which is ten dollars or more per ton. (Sec. 1).

Statement of analysis. Before any commercial fertilizer can be legally sold or offered for sale in the State the net weight of the package, the name of the brand and name and address of the manufacturer must be printed on the bag or on a card attached to the bag together with the guaranteed analysis in the following form:

Nitrogen .... %
Available Phosphoric Acid .... %
Total Phosphoric Acid .... %
Potash (K_2O) .... %

No other form stating the guarantee is permissible. The attention of manufacturers who use the sliding guarantees and the equivalent guarantees is particularly called to the above form of stating the guaranteed analysis. (Sec. 1).

Registration. Before any commercial fertilizer is sold or offered for sale, the party selling or offering the same for sale shall file with the Chemist of the Experiment Station a certified copy of the analysis and also a sealed glass jar containing not less than two pounds of such fertilizer, with an affidavit that it is a fair sample of the article to be sold or offered for sale. Registration blanks for this purpose will be furnished on application. Registrations must be made on all brands each year but samples are required only at the time of the first registration. It is the ruling of this Department that any change in the brand name or in the guarantee constitutes a new brand. (Sec. 2).

License fee. A license fee of twenty dollars for each brand of fertilizer sold or offered for sale should be paid on or before May 1st of each year or before the fertilizer is offered for sale in the State. All checks covering license fees should be made payable to the Secretary, State Board of Agriculture. (Sec. 3).

Penalties. Any person or persons who shall be found guilty of selling or offering for sale any commercial fertilizer in violation of the provisions of the law shall be fined not less than one hundred dollars for the first offense and not less than three hundred dollars for each subsequent offense. (Sec. 6).

DEALERS.

Companies to represent. Represent only such companies as properly register all the brands they send into the State. Before accepting a shipment of fertilizers for resale find out by writing to the Chemist of the Experiment Station if the registration has been made and the license fee paid.

Storing. Fertilizers should be stored in a dry, waterproof building and should never be piled directly on the ground. Failure to observe this precaution may cause the fertilizers to absorb an unusual amount of moisture and, consequently, to run below guarantee. Furthermore, improperly stored fertilizer is liable to become hard, in which condition it cannot be handled in a drill without regrinding and even distribution by hand is much more difficult. When two or more brands of fertilizer are stored in the same building they should be separated by a narrow aisle to insure against the brands getting mixed.

Sampling. Any duly authorized agent of the State Board of Agriculture is empowered to select samples, for the purpose of analysis, from any commercial fertilizer exposed for sale in the State. All inspectors sent out for this purpose will be provided with an authorization signed by the Secretary of the State Board of Agriculture and only such persons have authority to collect samples.

CONSUMERS.

The fertilizer law is for your protection, therefore do not purchase unlicensed fertilizers from dealers outside of the State, even when offered at a great bargain, for, in such cases, the law can offer you no protection.

Do not send samples for analysis without first writing to the Chemist of the Experiment Station for instruction in regard to taking the sample. This is very important as this Department will analyze only those samples secured by the regular inspectors or those taken in accordance with our instructions.

Consult the fertilizer bulletins and find out what companies are most consistently fulfilling their obligations as to the amounts of plant-food guaranteed.

Low crop yields may be due to any one of a number of causes such as poor drainage, soil acidity, poor physical condition, insufficient moisture, unfavorable climatic condition, lack of available plant-food, etc. Fertilizers can correct only one of these causes, namely, lack of plant-food, and they should not be condemned when they fail to produce results if the real cause of low yields is due to some other condition.

The best results from the use of commercial fertilizers will be obtained, only, when all of the conditions affecting plant growth are as nearly perfect as it is possible to make them. "Fertilizers are foods (not stimulants) for healthy soils. They are not medicine for sick land."

Study your soil conditions and by experimenting determine what forms of plant-food, if any, are required and in what amounts they should be used to produce the most economical results. Only in this way can these questions be definitely answered.

LICENSED BRANDS.

Thirty-six manufacturers and fertilizer companies have licensed 303 distinct brands for sale in the State during the season of 1915. The brands appearing in the following tables of analyses, and none others, can be legally sold.

Parties mixing or importing fertilizers for their own use and not for sale are not affected by the restrictions of the law and neither are they protected under it.

COLLECTION OF SAMPLES.

The analyses reported in this bulletin were made on samples collected by inspectors sent out from the Experiment Station. The inspectors cover practically all parts of the State where fertilizers are sold, and the samples are drawn from stock in the hands of dealers by means of a specially constructed tube with which a core from the entire length of the bag is secured. In no case is a sample taken from a lot containing less than five bags nor from a bag that has previously been opened. The samples are drawn and sealed in the presence of a witness and shipped to the laboratory for analysis. For the first time, samples were taken of the fall shipments and the analyses reported in this bulletin represent both spring and fall shipped goods. The inspectors failed to find three of the licensed brands on the market and upon investigation it was found that in one of these cases at least, the particular brand was not shipped into the State.

RESULTS OF INSPECTION.

(a) Quantity of plant-food.

A study of the tables of analyses shows that, of the 358 samples analyzed, representing 300 brands, 74 (20.7%) are below guarantee* in one or more constituent. Twenty-one (5.9%) are below guarantee in nitrogen, 19 (5.3%) are below in available phosphoric acid, 5 (1.4%) in total phosphoric acid and 33 (9.2%) in potash.

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*A shortage of more than 0.10 per cent of nitrogen or more than 0.20 per cent available phosphoric acid or potash is considered below guarantee.

A summary of the results of the inspection is given in the following table:

Manufacturer.	No. of brands licensed.	No. of samples analyzed.	No. below guarantee in one or more ingredient.	No. equal in value to guarantee.	No. not within 5 per cent of value guaranteed.	No. not within 10 per cent of value guaranteed.	No. 5 per cent or more above value guaranteed.
American Agricultural Chemical Co.	67	76	6	73	0	0	65
Ann Arbor Abattoir Co.	1	1	1	1	0	0	1
Armour Fertilizer works	21	28	14	25	1	0	18
Robert Binder Co.	1	1	1	0	0	0	0
Jas. Boland Rendering & Fertilizer Co.	2	2	2	1	0	0	0
Edward Burton	1	1	1	1	0	0	0
Chicago Feed & Fertilizer Co.	1	1	0	1	0	0	1
Chicago Raw Products Co.	9	8	1	8	0	0	6
Darling & Company	13	19	6	17	1	0	15
German Kali Works	3	3	0	3	0	0	2
Gleaner Clearing House Association	6	6	4	6	0	0	6
Grand Rapids Glue Co.	1	1	0	1	0	0	1
Grange Fertilizer Co.	7	7	0	7	0	0	6
W. C. Harger	1	1	1	1	0	0	0
Hirsh, Stein & Co.	19	26	6	26	0	0	21
Independent Packers Fert. Co.	7	9	3	8	0	0	8
International Agricultural Corporation	14	13	0	13	0	0	13
The Jarecki Chemical Co.	11	12	1	12	0	0	10
Kalamazoo Rendering & Fertilizer Co.	2	2	2	2	0	0	2
Natural Guano Co.	1	2	0	2	0	0	2
Nitrate Agencies Co.	3	4	1	4	0	0	3
Ohio Standard Chemical Co.	2	1	0	1	0	0	1
The Packers Fert. Co.	8	10	1	10	0	0	8
Pulverized Manure Co.	2	2	1	2	0	0	1
The Queen City Fertilizer Co.	1	1	0	1	0	0	0
Rasin Monumental Co.	15	16	0	16	0	0	16
F. S. Royster Guano Co.	12	14	1	13	0	0	10
The Smith Agricultural Chemical Co.	11	12	0	12	0	0	12
Elmer D. Smith & Co.	1	2	2	0	1	0	0
Speidel & Swartz	1	1	1	1	0	0	0
J. L. & H. Stadler Rendering & Fertilizer Co.	11	12	2	11	1	0	11
G. B. Stock Xylite Grease & Oil Co.	1	1	0	1	0	0	1
Swift & Co.	32	44	11	42	0	0	32
The Toledo Seed & Oil Co.	1	2	0	2	0	0	2
Tuscarora Fert. Co.	7	7	1	7	0	0	6
The Wuichet Fert. Co.	7	10	4	7	1	0	6
Total	303	358	74	338	5	0	286

(b) Quality of plant-food.

Attention is again called to the quality of the nitrogen furnished in the various brands of fertilizer sold in the State. As was pointed out in the 1914 fertilizer bulletin the materials used to furnish the nitrogen are many and of greatly varying availability. A close study of the results contained in the tables under the heading "Nitrogen" is recommended to every user of commercial fertilizers. In interpreting these results, the following points should be remembered: That water-soluble nitrogen is readily available for plant uses. That the water-insoluble nitrogen ("active insoluble" and "inactive insoluble") may or may not be readily available for plant uses.

When the amount of "active insoluble" nitrogen is greater than the amount of "inactive insoluble" nitrogen, the total water-insoluble nitrogen is considered to be readily available to plants; when the amount of *"active insoluble" nitrogen is less than the "inactive insoluble" nitrogen the total water-insoluble nitrogen is not considered to be readily available and the plants may fail to derive any benefit from its use.*

Many of the fertilizer brands reported in this bulletin, especially those having small percentages of nitrogen, show a large proportion of the nitrogen to be in water-insoluble forms of questionable quality.

THE POTASH SITUATION.

All of the potash used by the fertilizer trade has, in the past, been supplied by the immense potash mines of Germany. Owing to conditions, incident to the war in Europe, the German Government placed an absolute embargo on the exportation of potash in January, 1915, since which time, none has been shipped into this country. In order to conserve the supply then in the hands of the fertilizer manufacturers, all brands, containing over three per cent potash, with the exception of a very few, were withdrawn from sale during the past season. For the 1916 season it will be necessary to reduce the amount offered in complete fertilizers still further and it has been reported that no brands will be placed on the market containing more than one per cent potash.

The demand for potash in other industries has caused the price of the unmixed potash salts to advance until they are now selling at ten to twelve times the normal value. This is entirely out of proportion to their agricultural value.

The government, through the Department of Agriculture and Geological Survey, has made extensive explorations for potash sources in this country but up to the present the search has not been productive of results that promise any immediate relief. The investigations already made, however, indicate that it may sometime be possible to produce in this country sufficient potash to provide for our own needs. The most promising sources are: the alunite deposits in the mountains of Utah and neighboring states; the feldspathic rocks of the eastern states; the giant kelp of the Pacific coast and the mud of Searles Lake in California.

THE PHOSPHATE SITUATION.

Acid phosphate is the basis of all mixed fertilizers. This is made by treating phosphate rock with sulfuric acid. The supply of phosphate rock in this country is almost unlimited with large deposits in Tennessee, South Carolina, Florida and several of the western states. The phosphoric acid in the rock is not readily available in its natural condition but is made so by the treatment with sulfuric acid. In the usual process of manufacture one ton of sulfuric acid is used for each ton of phosphate rock.

Owing to the greatly increased demand for sulfuric acid in the manufacture of war munitions, the price has risen from $5.00 to $6.00 per ton to about $25.00 per ton. This necessarily increases the cost of manufacturing acid phosphate and explains the rise in the price of this material.

GENERAL SUGGESTIONS.

On account of these unusual conditions it is imperative that all waste materials on the farm, especially those containing potash, be preserved. Of the organic substances, stable manure is the most important. The floors in stalls and stables should be made tight and enough bedding used to hold the liquid manure since nearly all the potash and the most valuable part of the nitrogen of manure is in the urine. All waste materials of organic nature such as leaves, stalks and trash should be used for bedding or composted with manure. Average stable manure contains, in each ton, about 10 lbs. of nitrogen, 5 lbs. of phosphoric acid and 10 lbs. of potash.

All the ashes from wood fires and from the burning of brush and other waste material should be saved and stored under cover until used. Unleached hardwood ashes contain from 5 to 10 per cent of water-soluble potash and about 60 per cent of lime. Leached ashes usually contain less than one per cent of potash. Wood ashes should be bought on a guarantee of water-soluble potash with provision for a rebate if the guarantee is not fully met. Coal ashes contain neither potash nor lime except in very small amounts.

Tobacco stems and clippings contain from 5 to 8 per cent of potash and from 2 to 3 per cent of nitrogen. These may be composted with manure or they may be plowed under separately. In either case, it would be advisable to supplement with acid phosphate, especially when used for corn, sugar beets or potatoes.

Muck lands will be most seriously affected by the lack of potash as they contain less of this plant-food than the mineral types of soil. On such soils it is suggested that manure, especially horse manure without too much coarse litter be used at the rate of 10 to 12 tons per acre and that the soils be well compacted by rolling several times with a well weighted roller.

On the upland soils some benefit may be gained by plowing a little deeper and by cultivating the soil very thoroughly. Tillage tends to release the insoluble potash, make the nitrogen compounds more available and to conserve the soil moisture.

In conclusion it is advised that fertilizers be used only on the best lands next spring. At the present prices, it will not pay to attempt to build up poor soils with them.

Samples were drawn from stock in the hands of the following list of dealers:

Adrian—J. E. Bennett, W. R. Bradish, Cutler Dickerson Co., Elmer D. Smith & Co., J. C. Van Doren, C. E. Winnie.

Albion—F. E. Nowlin & Co.

Alma—J. M. Monugal.

Almont—Frank Bishop.

Anchorville—Fred Brockmiller, C. L. Bethny.

Ann Arbor—Gensley Bros., Ann Arbor Abattoir Co.

Atkins—J. J. Norman.

Bad Axe—The Farmers Elevator & Prod. Co.

Bangor—M. D. Trim Co.

Battle Creek—Robt. Binder Est., Armstrong & Brown, A. K. Zimm, Powers & Co.

Bay City—Mohr Hardw. Co.
Beech—Geo. W. Burt, Geo. Wright.
Belleville—Alban Lumber Co., Van Schoick Bros.
Benton Harbor—Cutler Downing Co., Collis & Westcot.
Birch Run—Chas. Wolohan.
Birmingham—H. B. Parks, M. Spencer, F. Pool.
Blaine—Dan Maynard, C. Rutledge.
Blissfield—E. A. Beamer, E. J. Gray, Continental Sugar Co.
Brown City—Geo. H. Palmer.
Buchanan—Chas. F. Boyle.
Cadmus—Lomb Bros.
Camden—Geo. Tanner, Geo. Palmer.
Capac—L. R. Glassford.
Caro—Irving Jaynes.
Carsonville—Harvey McGregor.
Charlotte—Hartel & Martin, Z. W. Fowler.
Clinton—Atlas Milling Co.
Coats Grove—John Blocher.
Coldwater—S. I. Treat & Son.
Coloma—Reuben Hazen, Clyde Lockwood, Coloma Hardw. Co.
Coopersville—Reynolds Bros., M. Durham.
Covert—E. L. Walters, J. R. Spellman & Co.
Croswell—Farmers Elevator Co.
Davison—O. K. Hathaway, Daniel Hull.
Dearborn—S. D. Lapham.
Deckerville—E. Shaffbower.
Deerfield—Chas. Helzer, C. A. Robison.
Denton—Lee Newton.
Detroit—Lohrman Seed Co., Schemen & Mok.
Dundee—Michigan Milling Co.
Durand—Eph. Judson, Judson Michigan Bean Co.
Eckford—L. D. Sackett.
Elm—Bentley Bros., Ira Wilson.
Emmett—Frank Kough.
Farmington—Chas. F. Gowe.
Flat Rock—J. Neifert.
Flint—Wolcott Packing Co., Burroughs & Son, W. A. Holtslander.
Galesburg—Zinn & Austin.
Galien—Fred Koenigshof.
Grand Haven—Speidel & Swartz.
Grand Rapids—Grand Rapids Glue Co., Reed & Cheney, Brown Seed Co.
Grant—Grant Coop. Creamery.
Harbor Beach—John Hildebrandt, Jake Deer.
Hartford—H. L. Gleason & Son.
Hillsdale—Wm. Cole, Hillsdale Co. Coop. Assn.
Holland—Mulder & Son.
Homer—E. R. Fish.
Howell—Jacob First.
Hudson—J. A. Dillon, Jr.
Ida—Geo. Schuler.

Imlay City—Roy Churchill, Chas. Starkey.
Ithaca—D. Heffer & Son.
Jackson—Isbell Seed Co., Jas. Boland Rend. & Fert. Co., State Prison, J. C. Bartlet.
Jeddo—Jeddo Elevator Co.
Jonesville—A. H. Dudley, Jonesville Milling Co.
Kalamazoo—Woodhams, Oakley & Oldfield Co., Geo. Martin.
Keeler—Nate Simpson, Jr.
Lansing—J. A. Bissinger.
Lawton—Michigan Fruit Ex., Chas. G. Hall, C. Dunham.
Lennon—Lennon Grain Co.
Linwood—J. J. Lambert.
Lulu—C. Vandercook.
Mancelona—Jas. A. Gaylord.
Manitou Beach—Riley Bros.
Marine City—J. Mosier.
Marlette—Marlette Hay & Produce Co.
Marshall—J. C. Beckwith.
Mason—A. A. Howlett.
Maybee—Hugo Lickfelt.
Memphis—T. W. McCall, Fred G. Coburn.
Mikado—Mikado Elevator Co.
Minden City—L. H. Reidel & Son.
Monroe—G. R. Hurd & Co.
Montgomery—Tri-State Coop. Assn., Geo. Pierce, O. K. Coolman, W. W. Crawford.
Montrose—L. M. Gunnings.
Morenci—Chas. Fay, Bert Spencer.
Mt. Clemens—Wolff Bros., A. S. Clark, A. Seibert.
Mt. Morris—J. B. Leach & Co.
Muskegon—John Stegink, J. Marvin, J. Leng Bros.
New Baltimore—E. D. W. Laforge.
New Boston—E. Gumtow, B. Hasselbach, Fred Knope, Jas. Vogt, R. E. Krause.
New Buffalo—Seigmund Bros.
Northville—Robt. Gibson.
Nunica—J. D. Pickett, R. S. Brown.
Ogden—Walper & Heiser.
Onstead—Onstead & Kar.
Owosso—W. E. Payne.
Palms—Palms Elev. Co.
Palmyra—A. G. Rood.
Paw Paw—F. A. Sturtevant.
Pigeon—John H. Doepker.
Pittsford—Carl & Childs.
Plymouth—C. R. Carson, J. D. McLaren, M. L. Horton, A. Warner, H. C. Hager, L. A. Wisely, H. S. Shattuck, A. B. Schroder, Geo. Hake, C. E. Ryder.
Pompeii—Geo. L. Jessop.
Pontiac—Gem Wire Fence Co., W. C. Harger.
Portage—C. Nederhoed.

Port Huron—B. B. Hyde, G. B. Stock Co.
Quincy—Philo Corliso, H. B. Walbridge, W. A. Lott.
Raisin Center—F. V. Judson.
Reading—W. M. Cahow, E. Davis, L. Quackenbush, Rus Riggleman, Wm. Neddermeyer, Kellogg & Youngs.
Redford—Geo. E. Fisher, Steve Wright.
Richmond—Farmers Elev. Co.
Riga—Otto Wegner, C. G. Schwyn.
Rochester—Robt. Castel.
Romeo—Bradley & Chubb, Romeo Implement Co., W. Allen, Gray Elevator Co.
Royal Oak—John Starr.
Saline—Herman Grass.
Samaria—S. L. Smith, E. J. Harwick.
Sandusky—John Murphy.
Silverwood—H. L. Chaffee.
Southfield—Johnson.
South Haven—South Haven Fruit Exchange.
St. Clair—Recor & Smith, John Man, Chris Ahlas.
St. Louis—St. Louis Hardw. Co.
St. Joseph—John Wallace Sons, Edw. Burton.
Stevensville—F. P. Cupp.
Sturgis—G. R. Turner.
Swartz Creek—Swartz Creek Grain Co.
Taylor Center—A. Boelter.
Tecumseh—Temple & Co., Brown & Co., Tecumseh Coop. Assn., Moore Bros.
Temperance—John Lord.
Three Oaks—Warren Featherbone Co.
Three Rivers—John Griffith Co., F. T. Garl.
Trenton—H. L. Wagar.
Troy—Bert Tyke, Geo. Houghten.
Vassar—Farmers Elevator Co.
Vriesland—T. W. Van Haitsma.
Waltz—Jas. Schneider.
Watervliet—Rosenberg & Forbes.
Wayne—E. H. Langworthy, E. R. Barker, Hilliards & Reiser, Wortz & Co.
Willow—H. C. Otter.
Woodland—W. A. Grozinger.
Wyandotte—F. C. Wells, J. J. Kreger, Fred Bush.
Yale—Geo. W. Elston.
Ypsilanti—Frank Begole, B. G. Moorman & Son.
Zeeland—Isaac Van Dyke, Vanhoven & Vereeke.

ANALYSES OF COMMERCIAL FERTILIZERS FOR 1915, EXPRESSED IN PARTS IN ONE HUNDRED.

Laboratory number.	Manufacturer and Trade Name.	Nitrogen.					Phosphoric Acid.				Potash.	
		As soluble.	As active insoluble organic.	As inactive insoluble organic.	Total found.	*Total guaranteed.*	Total.	Insoluble.	Available fund.	*Available guaranteed.*	Total found.	*Total guaranteed.*
	American Agricultural Chemical Company, Detroit, Mich.											
4591	A. A. Complete Fertilizer	1.06	0.45	0.40	1.91	*1.65*	11.10	1.90	9.20	*8.00*	3.62	*3.00*
4656	All Grain Fertilizer	1.18	0.43	0.16	1.77	*1.65*	14.90	1.42	13.48	*12.00*	3.00	*3.00*
11155	Amo-Phos Fertilizer	1.36	0.43	0.25	2.04	*1.65*	14.80	0.96	13.84	*12.00*		
91522	Amo-Phos & Potash Fertilizer	0.32	0.47	0.24	1.03	*0.82*	12.65	1.74	10.91	*10.00*	0.95	*1.00*
4924	16% Acid Phosphate						20.05	1.06	18.99	*16.00*		
4922	Banner Dissolved Bone						38.20	2.64	35.56	*34.00*		
4923	Beet Fertilizer	0.73	0.38	0.32	1.43	*1.23*	12.10	2.06	10.04	*9.00*	2.00	*2.00*
9153	Extra Phos & Potash Formula						21.98	2.24	19.74	*18.00*	1.89	*2.00*
4762	Fine Ground Bone	0.79	1.51	0.51	2.81	*2.47*	23.10			**20.00*		
4763	Michigan Bean Grower	0.93	0.48	0.44	1.85	*1.65*	10.90	2.40	8.50	*8.00*	3.02	*3.00*
4593	New York State Special	0.63	0.35	0.24	1.22	*0.82*	11.30	1.26	10.04	*8.00*	3.16	*3.00*
4592	XXX Standard Fertilizer	1.64	0.56	0.25	2.47	*2.47*	12.95	1.52	11.43	*10.00*	3.40	*3.00*
4947	3-8-3 Fertilizer	1.74	0.56	0.30	2.60	*2.47*	11.60	1.64	9.96	*8.00*	3.54	*3.00*
4594	Nitrate of Soda	15.52			15.52	*15.00*						
	Bradley Brands.											
4925	Acid Phosphate						13.65	1.80	11.85	*10.00*		
4657	Alkaline Phosphate and Potash						12.85	0.92	11.93	*10.00*	1.83	*2.00*
91510	Alkaline Phosphate and Potash						11.83	0.93	10.90	*10.00*	**1.04**	*2.00*
12154	Alkaline Phosphate and Potash						11.27	1.03	10.24	*10.00*	**1.66**	*2.00*
4658	B. D. Sea Fowl Guano	0.78	0.70	0.46	1.94	*2.06*	11.30	2.30	9.00	*8.00*	1.54	*1.50*
4595	Dissolved Bone Phosphate with Potash	0.50	0.35	0.38	1.23	*1.03*	11.10	1.70	9.40	*8.00*	2.16	*2.00*
4596	Niagara Phosphate	0.40	0.28	0.27	0.95	*0.82*	10.00	1.94	8.06	*7.00*	0.80	*1.00*
4959	Niagara Phosphate	0.57	0.22	0.32	1.11	*0.82*	10.25	1.76	8.49	*7.00*	1.03	*1.00*
4926	Soluble Dissolved Bone Phosphate						17.80	1.40	16.40	*14.00*		
4597	Special Potash Fertilizer	0.51	0.20	0.30	1.01	*0.82*	11.00	1.62	9.38	*8.00*	2.90	*3.00*

	Crocker Brands.											
4598	Ammoniated Wheat & Corn Phosphate	1.23	0.67	0.40	2.30	*2.06*	11.20	2.20	9.00	*8.00*	1.48	*1.50*
4599	Dissolved Bone and Potash						13.15	1.42	11.73	*10.00*	2.14	*2.00*
4600	General Crop Phosphate	0.49	0.27	0.24	1.00	*0.82*	9.90	1.82	8.08	*7.00*	0.99	*1.00*
4764	New Rival Ammoniated Superphosphate	0.72	0.40	0.34	1.46	*1.23*	12.05	1.80	10.25	*9.00*	2.00	*2.00*
4601	Universal Grain Grower	0.56	0.35	0.34	1.25	*0.82*	10.90	1.60	9.30	*8.00*	2.08	*2.00*
	Michigan Carbon Works Brands.											
4605	A-1 Potash Fertilizer	0.54	0.22	0.35	1.11	*0.82*	11.50	1.76	9.74	*8.00*	3.18	*3.00*
91538	Banner Phosphate & Potash Compound						23.35	2.48	20.87	*18.00*	2.28	*2.00*
91524	Banner Phosphate & Potash Compound						21.65	2.19	19.46	*18.00*	1.88	*2.00*
91521	Bialode Fertilizer	0.16	0.54	0.27	0.97	*0.82*	12.68	2.14	10.54	*10.00*	0.92	*1.00*
4661	Red Line Complete Manure	0.40	0.22	0.28	0.90	*0.82*	10.25	1.74	8.51	*7.00*	1.02	*1.00*
4928	Red Line Phosphate						17.50	1.28	16.22	*14.00*		
4606	Red Line Phosphate with Potash						11.35	1.06	10.29	*10.00*	2.52	*2.00*
4927	Superior Acid Phosphate						20.20	1.02	19.18	*16.00*		
10151	Triaton Fertilizer	1.33	0.34	0.31	1.98	*1.65*	14.30	1.08	13.22	*12.00*		
4672	Wolverine Phosphate						11.85	1.00	10.85	*10.00*		
	Michigan Carbon Works Homestead Brands.											
4602	AAA Fertilizer	1.88	0.56	0.20	2.64	*2.47*	13.20	1.18	12.02	*10.00*	2.73	*3.00*
4960	AAA Fertilizer	1.79	0.52	0.26	2.57	*2.47*	12.13	1.46	10.67	*10.00*	3.68	*3.00*
4961	AAA Fertilizer	1.72	0.54	0.21	2.47	*2.47*	13.75	1.48	12.27	*10.00*	3.58	*3.00*
4765	Bean Fertilizer	1.17	0.33	0.20	1.70	*1.65*	10.30	1.76	8.54	*8.00*	5.05	*3.00*
4603	Bone Black Fertilizer	1.85	0.09	0.29	2.23	*2.06*	10.80	0.08	10.72	*8.00*	1.91	*1.50*
4604	General Fertilizer	0.93	0.48	0.44	1.85	*1.65*	11.45	2.66	8.79	*8.00*	3.02	*3.00*
91523	Grain Fertilizer	0.95	0.37	0.21	1.53	*1.65*	14.45	1.32	13.13	*12.00*	3.38	*3.00*
4659	Grain Fertilizer	0.83	0.77	0.32	1.92	*1.65*	15.40	1.76	13.64	*12.00*	3.34	*3.00*
4660	Sugar Beet Fertilizer	0.69	0.38	0.39	1.46	*1.23*	12.80	1.74	11.06	*9.00*	2.08	*2.00*
	Niagara Brands.											
4766	Dissolved Bone and Potash						12.35	1.36	10.99	*10.00*	2.08	*2.00*
4767	Grain and Grass Grower	0.47	0.24	0.26	0.97	*0.82*	10.05	1.74	8.31	*7.00*	1.01	*1.00*
4607	Wheat and Corn Producer	0.72	0.38	0.35	1.45	*1.23*	13.05	1.76	11.29	*9.00*	2.00	*2.00*
	North Western Horse Shoe Brands.											
4929	Acidulated Bone Phosphate and Potash	0.32	0.49	0.21	1.02	*0.82*	12.85	1.40	11.45	*10.00*	1.04	*1.00*
4663	Animal Bone Phosphate Manure	0.39	0.19	0.28	0.86	*0.82*	10.00	1.94	8.06	*7.00*	1.09	*1.00*
91539	Bean Special	0.83	0.46	0.40	1.69	*1.65*	12.00	3.10	8.90	*8.00*	2.81	*3.00*

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*Total phosphoric acid.

ANALYSES OF COMMERCIAL FERTILIZERS FOR 1915, EXPRESSED IN PARTS IN ONE HUNDRED.—*Continued.*

Laboratory number.	Manufacturer and Trade Name.	Nitrogen.					Phosphoric Acid.				Potash.	
		As soluble.	As active insoluble organic.	As inactive insoluble organic.	Total found.	*Total guaranteed.*	Total.	Insoluble.	Available found.	*Available guaranteed.*	Total found.	*Total guaranteed.*
	American Agricultural Chemical Co.—Con.											
4664	Bone Phosphate and Potash						13.35	1.12	12.23	*10.00*	2.56	*2.00*
4608	Corn and Wheat Grower	1.11	0.43	0.35	1.89	*1.65*	11.35	1.84	9.51	*8.00*	2.10	*2.00*
10152	Dissolved Ammoniated Bone Phosphate	1.44	0.45	0.06	1.95	*1.65*	14.20	1.12	13.08	*12.00*		
4665	Garden City Superphosphate	1.18	0.70	0.41	2.29	*2.06*	11.15	2.54	8.61	*8.00*	1.60	*1.50*
4609	Potash Manure	0.52	0.25	0.35	1.12	*0.82*	11.35	1.62	9.73	*8.00*	3.36	*3.00*
4666	Quick Acting Phosphate						12.25	1.10	11.15	*10.00*		
4667	Special Grain Fertilizer	0.82	0.76	0.29	1.87	*1.65*	14.45	1.62	12.83	*12.00*	3.06	*3.00*
4930	Square Deal Phosphate						17.20	1.28	15.92	*14.00*		
4668	Sugar Beet Fertilizer	0.74	0.38	0.37	1.49	*1.23*	12.35	2.10	10.25	*9.00*	2.10	*2.00*
4662	16% Phosphate						20.60	0.98	19.62	*16.00*		
91540	18 and 2 Fertilizer						22.75	2.38	20.37	*18.00*	2.10	*2.00*
	Packers Boar's Head Brands.											
4932	Best Grain Fertilizer	0.72	0.81	0.20	1.73	*1.65*	13.75	1.44	12.31	*12.00*	3.06	*3.00*
91514	Corn and Wheat Grower	1.21	0.33	0.24	1.78	*1.65*	10.83	1.97	8.86	*8.00*	2.28	*2.00*
91520	Dissolved Phosphate and Potash						12.95	1.13	11.82	*10.00*	**1.29**	*2.00*
121513	Dissolved Phosphate and Potash						11.30	1.04	10.26	*10.00*	**1.67**	*2.00*
4933	Dissolved Phosphate and Potash						12.95	1.60	11.35	*10.00*	**1.47**	*2.00*
4934	Faultless Grain Grower	0.53	0.36	0.30	1.19	*0.82*	11.45	1.86	9.59	*7.00*	2.07	*1.00*
4935	Gilt Edge Phosphate						17.80	1.60	16.20	*14.00*		
4936	Soluble Phosphate						13.95	1.72	12.23	*10.00*		
4931	Sugar Beet Grower	0.74	0.38	0.28	1.40	*1.23*	11.85	1.92	9.93	*9.00*	1.81	*2.00*
4610	Sure Growth Potash Manure	0.52	0.26	0.36	1.14	*0.82*	10.75	1.64	9.11	*8.00*	3.08	*3.00*
4611	World of Good Superphosphate	1.13	0.67	0.43	2.23	*2.06*	11.65	2.78	8.87	*8.00*	1.50	*1.50*
	Ann Arbor Abattoir Co., Ann Arbor, Mich.											
4768	"3-A" Blood and Bone Meal	4.86	1.80	0.61	7.27	*6.60*	14.00	6.96	7.04	*4.20*	**0.28**	*1.62*

	Armour Fertilizer Works, Chicago, Ill.											
4963	Bone Meal	0.50	1.06	0.45	2.01	1.65	**24.70**	....	....	*27.00	....	....
4964	Bone Meal	0.55	1.17	0.33	2.05	1.65	**25.10**	....	....	*27.00	....	....
4673	Bone Meal	0.44	1.18	0.46	2.08	1.65	**24.10**	....	....	*27.00	....	....
4677	Standard	0.33	0.38	0.26	0.97	0.82	9.60	0.98	8.68	8.00	2.88	3.00
4965	12-2 Fertilizer	....	....	....	....	....	13.80	0.36	13.44	12.00	**1.54**	2.00
4966	12-2 Fertilizer	....	....	....	....	....	13.30	0.34	12.96	12.00	**1.56**	2.00
4680	12-2 Fertilizer	....	....	....	....	....	13.35	0.38	12.97	12.00	**1.73**	2.00
91515	1-9-1 Fertilizer	0.57	0.34	0.32	1.23	0.82	12.10	1.31	10.79	9.00	1.04	1.00
91542	1-12-1 Fertilizer	0.39	0.37	0.27	1.03	0.82	14.50	1.28	13.22	12.00	1.02	1.00
4681	1-14-2 Fertilizer	0.50	0.44	0.29	1.23	0.82	16.80	1.42	15.38	14.00	**1.47**	2.00
4682	2-8-3 Fertilizer	0.94	0.55	0.25	1.74	1.65	10.70	1.26	8.44	8.00	2.92	3.00
4683	2-10-2 Fertilizer	0.50	0.44	0.36	**1.30**	1.82	12.05	1.90	10.15	10.00	2.02	2.00
4613	3-8-3 Fertilizer	1.34	0.64	0.43	2.41	2.47	11.30	1.84	9.46	8.00	3.14	3.00
4967	4-12-3 Fertilizer	0.51	1.93	0.56	**3.00**	3.29	14.40	0.32	14.08	12.00	3.04	3.00
4769	4-12-3 Fertilizer	1.49	1.08	0.49	**3.06**	3.29	14.20	0.32	13.88	12.00	3.60	3.00
4684	4½-9-3 Fertilizer	2.00	1.45	0.42	3.87	3.70	10.70	0.24	10.46	9.00	3.50	3.00
4685	5-10-3 Fertilizer	2.75	0.51	0.39	**3.65**	4.11	13.25	1.76	11.49	10.00	3.30	3.00
4962	Bone Meal, Phosphate & Potash	0.61	0.86	0.41	1.88	0.82	20.35	11.28	**9.07**	13.00	2.00	2.00
4674	Bone Meal, Phosphate & Potash	0.58	0.44	0.26	1.28	0.82	18.42	8.51	**9.91**	13.00	2.10	2.00
91541	Cereal Phosphate	....	....	....	....	....	11.50	0.60	10.90	10.00	....	....
4675	Grain & Bean Special	0.43	0.43	0.37	1.23	0.82	10.30	1.68	8.62	8.00	1.88	2.00
91519	Grain & Bean Special	0.38	0.42	0.29	1.09	0.82	10.08	1.48	8.60	8.00	**1.76**	2.00
4612	Grain Grower	0.73	0.60	0.47	1.80	1.65	11.70	2.28	9.42	8.00	1.97	2.00
4676	Phosphate & Potash	....	....	....	....	....	10.70	0.28	10.42	10.00	2.10	2.00
4678	Star Phosphate	....	....	....	....	....	16.50	0.24	16.26	14.00	....	....
4679	Wheat Corn and Oats Special	0.25	0.31	0.27	0.83	0.82	9.05	1.16	7.89	7.00	0.90	1.00
4939	Nitrate of Soda	15.56	....	....	15.56	14.80	....	....	....	....	....	....
10153	18% Phosphate	....	....	....	....	....	19.80	1.04	18.76	18.00	....	....
	Robert Binder Co., Battle Creek, Mich.											
4686	Blood & Bone	1.47	3.17	1.19	5.83	5.25	11.87	5.66	**6.21**	13.17	....	....
	The James Boland Rendering & Fertilizer Co., Jackson, Mich.											
4687	Blackman Boland Complete	0.39	0.66	0.68	1.73	1.50	15.90	5.04	**10.86**	13.00	1.50	1.50
4688	Blackman General Crop	0.66	1.46	1.32	3.44	3.00	14.50	5.72	**8.78**	13.00	1.33	1.25

*Total phosphoric acid.

ANALYSES OF COMMERCIAL FERTILIZERS FOR 1915, EXPRESSED IN PARTS IN ONE HUNDRED.—*Continued.*

Laboratory number.	Manufacturer and Trade Name.	Nitrogen.					Phosphoric Acid.				Potash.	
		As soluble.	As active insoluble organic.	As inactive insoluble organic.	Total found.	Total guaranteed.	Total.	Insoluble.	Available found.	Available guaranteed.	Total found.	Total guaranteed.
	E. Burton, St. Joseph, Mich.											
4689	Meat and Bone Phosphate	1.21	2.22	1.03	**4.46**	5.00	14.55	7.96	**6.59**	*11.00	......	......
	Chicago Feed & Fertilizer Co., Chicago, Ill.											
4817	Magic	0.57	0.52	0.76	1.85	2.00	9.05	2.44	6.61	*8.00	2.38	1.50
	Chicago Raw Products Co., Chicago, Ill.											
	Consumers Special Brands.											
91544	Hummer Wheat Grower	0.15	0.25	0.70	1.10	1.00	12.00	1.26	10.74	10.00	0.40	0.50
10154	14% Acid Phosphate	......	......	......	......	......	18.20	1.56	16.64	14.00	......	......
4771	1-8-3 Farmers Favorite	0.17	0.23	0.39	0.79	0.82	9.75	0.38	9.37	8.00	3.08	3.00
10155	1-8-4 Corn & Wheat Grower	0.18	0.28	0.41	0.87	0.82	10.20	0.61	9.59	8.00	4.34	4.00
10156	1-20-8 Vine & Tree Fertilizer	0.21	0.30	0.16	**0.67**	0.82	21.30	......	......	*20.00	9.12	8.00
4814	2-8-2 Grain Grower	0.89	0.36	0.34	1.59	1.64	9.60	0.52	9.08	8.00	2.04	2.00
10157	2-8-5 Potato & Vegetable Grower	0.96	0.33	0.41	1.70	1.64	10.20	0.32	9.88	8.00	5.04	5.00
	11-3 Special Corn and Oats Fertilizer	......	......	......	......	......	......	......	......	11.00	......	3.00
4770	15-3 Special High Grade Wheat Grower	......	......	......	......	......	16.60	0.22	16.38	15.00	2.82	3.00
	Darling & Co., Chicago, Ill.											
9159	8% Acid Phosphate	......	......	......	......	......	10.80	1.41	9.39	8.00	......	......
4690	Big Harvest Special	0.75	0.70	0.29	1.74	1.60	15.10	1.12	13.98	12.00	4.00	3.00
4691	Bone Blend	0.26	0.61	0.36	1.23	0.80	18.30	......	......	*16.00	3.28	3.00
4614	Chicago Brand	0.69	0.59	0.59	1.87	1.60	11.60	1.88	9.72	8.00	2.26	2.00
4615	Farmer's Favorite Special	0.72	1.07	0.88	2.67	2.40	12.53	5.32	**7.21**	8.00	2.87	3.00
4968	Farmer's Favorite Special	0.71	1.25	0.68	2.64	2.40	12.65	5.09	**7.56**	8.00	3.22	3.00
4969	Farmer's Favorite Special	0.74	1.22	0.62	2.58	2.40	12.50	4.94	**7.56**	8.00	3.46	3.00
4692	High Grade Acid Phosphate	......	......	......	......	......	17.60	0.48	17.12	14.00	......	......
11158	Pure Bone & Potash	0.48	0.77	0.64	1.89	1.60	27.75	......	......	*27.00	2.63	2.00

4695	Pure Bone and Potash Special	0.46	0.85	0.53	1.84	*1.60*	26.80			**26.50*	3.12	*3.00*
4693	Pure Ground Bone	0.55	0.94	0.53	2.02	*1.60*	28.80			**28.00*		
4616	Sugar Beet & Root Grower Special	0.52	0.51	0.49	1.52	*1.60*	12.35	3.46	8.89	*8.00*	3.00	*3.00*
4970	Sugar Beet & Root Grower Special	0.52	0.63	0.44	1.59	*1.60*	11.15	2.78	8.27	*8.00*	3.40	*3.00*
4971	Sugar Beet & Root Grower Special	0.51	0.60	0.44	1.55	*1.60*	11.45	2.58	8.87	*8.00*	2.89	*3.00*
4617	Sure Winner Brand	0.23	0.34	0.38	0.95	*0.80*	11.45	2.86	8.59	*8.00*	3.00	*3.00*
4696	Twelve-Two Brand						14.80	3.51	**11.29**	*12.00*	**1.58**	*2.00*
4972	Twelve-Two Brand						16.75	2.78	13.97	*12.00*	**0.88**	*2.00*
9155	Wheat Grower	0.27	0.36	0.40	1.03	*0.82*	11.60	2.34	9.26	*9.00*	1.00	*1.00*
91511	Wheat Grower	0.25	0.27	0.30	0.82	*0.82*	13.08	1.88	10.20	*9.00*	**0.75**	*1.00*
	German Kali Works, New York, N. Y.											
10158	Kainit										14.16	*12.00*
10159	Muriate of Potash										48.74	*48.00*
101510	Sulfate of Potash										49.38	*47.00*
	Gleaner Clearing House Assn., Detroit, Mich.											
101511	14% Acid Phosphate						15.20	0.32	14.88	*14.00*		
4940	Phosphate & Potash						13.05	0.66	12.39	*10.00*	**1.61**	*2.00*
4618	1-8-2 Fertilizer	0.44	0.32	0.28	1.04	*0.82*	9.85	1.50	8.35	*8.00*	**1.67**	*2.00*
4973	1-8-2 Fertilizer	0.39	0.37	0.26	1.02	*0.82*	9.90	1.40	8.50	*8.00*	2.06	*2.00*
4941	1-14-2 Fertilizer				1.22	*0.82*	16.57	1.55	15.02	*14.00*	**1.72**	*2.00*
4619	2-8-2 Fertilizer	0.82	0.61	0.48	1.91	*1.65*	10.83	2.99	**7.84**	*8.00*	2.00	*2.00*
	Grand Rapids Glue Co., Grand Rapids, Mich.											
4697	Grand Rapids	1.11	0.78	0.68	2.53	*2.00*	18.27	11.83	6.44	*5.00*	0.20	*0.05*
	Grange Fertilizer Co., Detroit, Mich.											
4698	All Crops Special Fertilizer	0.49	0.20	0.32	1.01	*1.03*	11.10	1.64	9.46	*8.00*	2.02	*2.00*
4620	Complete Manure	0.42	0.26	0.25	0.93	*0.82*	10.00	2.16	7.84	*7.00*	0.98	*1.00*
4621	Corn Oats and Grass Fertilizer	0.94	0.46	0.49	1.89	*1.65*	11.70	2.76	8.94	*8.00*	2.19	*2.00*
4937	High Grade Concentrated Wheat Manure	0.65	0.38	0.33	1.36	*1.23*	11.75	2.18	9.57	*9.00*	1.87	*2.00*
4622	Potato and Vegetable Fertilizer	0.50	0.21	0.31	1.02	*0.82*	11.30	2.56	8.74	*8.00*	3.00	*3.00*
4699	Wheat Fertilizer No. 1						17.60	1.36	16.24	*14.00*		
4623	Wheat Fertilizer with Potash						12.80	1.46	11.34	*10.00*	2.14	*2.00*
	W. C. Harger, Pontiac, Mich.											
4778	Horse Brand	1.07	0.98	0.88	2.93	*2.75*	15.70	6.88	8.82	*5.90*	**2.67**	*4.00*

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*Total phosphoric acid.

ANALYSES OF COMMERCIAL FERTILIZERS FOR 1915, EXPRESSED IN PARTS IN ONE HUNDRED.—*Continued.*

Laboratory number.	Manufacturer and Trade Name.	Nitrogen.					Phosphoric Acid.				Potash.	
		As soluble	As active insoluble organic.	As inactive insoluble organic.	Total found.	*Total guaranteed.*	Total.	Insoluble.	Available found.	*Available guaranteed.*	Total found.	*Total guaranteed.*
	Hirsh Stein & Co., Chicago, Ill.											
	Calumet Brands.											
4700	Acid Phosphate	....	....	....	....	....	16.50	1.40	15.10	*14.00*	....	....
91545	Ammoniated Phosphate & Potash	0.16	0.17	0.52	0.85	*0.82*	11.60	1.28	10.32	*10.00*	0.86	*1.00*
4701	Bone Black Grain Grower	1.03	0.39	0.38	1.80	*2.05*	9.70	0.40	9.30	*8.00*	1.90	*1.50*
4974	Bone Black Grain Grower	1.34	0.36	0.42	2.12	*2.05*	10.45	0.86	9.59	*8.00*	1.52	*1.50*
4975	Bone Black Grain Grower	1.34	0.35	0.38	2.07	*2.05*	10.15	0.82	9.33	*8.00*	1.72	*1.50*
4702	Corn & Wheat Grower	0.21	0.39	0.30	0.90	*0.82*	9.35	0.18	9.17	*8.00*	4.02	*4.00*
91516	Farmers Favorite	0.72	0.26	0.15	1.13	*0.82*	14.60	0.78	13.82	*13.00*	1.33	*1.00*
4703	Grain Grower	0.80	0.44	0.40	1.64	*1.64*	10.35	0.50	9.85	*8.00*	2.12	*2.00*
4704	High Grade Garden & Vegetable Grower	0.73	0.53	0.52	**1.78**	*2.00*	11.20	1.44	9.76	*8.00*	5.81	*6.00*
101532	Hummer Wheat Grower	0.12	0.22	0.77	1.11	*1.00*	12.50	1.60	10.90	*10.00*	0.40	*0.50*
4773	Potato, Tobacco and Beet Grower	0.98	0.36	0.34	1.68	*1.64*	10.25	0.28	9.97	*8.00*	5.20	*5.00*
4774	Special Bone Phosphate & Potash	....	....	....	....	....	12.80	0.28	12.52	*11.00*	**2.59**	*3.00*
4624	Special Crop Grower	0.35	0.30	0.22	0.87	*0.82*	13.75	1.28	12.47	*11.00*	3.02	*3.00*
4707	Special Grape Fertilizer	0.19	0.45	0.14	0.78	*0.82*	22.70	....	....	**20.00*	7.85	*8.00*
4978	Special Grape Fertilizer	0.18	0.38	0.19	0.75	*0.82*	**19.20**	....	....	**20.00*	10.40	*8.00*
4976	Special High Grade Bone Phosphate & Potash	....	....	....	....	....	16.90	0.22	16.68	*15.00*	3.36	*3.00*
4977	Special High Grade Bone Phosphate & Potash	....	....	....	....	....	17.10	0.20	16.90	*15.00*	3.18	*3.00*
4775	Special Oats & Bean Fertilizer	0.24	0.34	0.42	1.00	*0.82*	11.05	0.48	10.57	*10.00*	2.40	*2.00*
4705	Special Pure Bone Meal	0.11	0.47	0.17	0.75	*0.82*	34.80	....	....	**29.77*	....	....
4706	Special Pure Bone Meal & Potash	0.16	0.50	0.20	0.86	*0.82*	**19.60**	....	....	**20.00*	5.34	*4.00*
4776	Special Sugar Beet Fertilizer	0.16	0.26	0.38	0.78	*0.82*	10.85	0.20	10.65	*8.00*	**2.72**	*3.00*
4979	Special Sugar Beet Fertilizer	0.21	0.24	0.32	0.77	*0.82*	10.55	0.44	10.11	*8.00*	3.00	*3.00*
4777	Sure Growth Fertilizer	0.27	0.25	0.32	0.84	*0.82*	8.80	0.40	8.40	*8.00*	2.38	*2.00*
4708	Wheat Corn & Oats Special	0.22	0.28	0.30	0.80	*0.82*	9.65	0.60	9.05	*8.00*	3.00	*3.00*
4709	Wheat Corn & Oats Special	0.27	0.28	0.38	0.93	*0.82*	10.70	0.54	10.16	*8.00*	**2.40**	*3.00*
91517	Wheat Corn & Oats Special	0.43	0.24	0.29	0.96	*0.82*	10.20	0.84	9.36	*8.00*	3.68	*3.00*

	The Independent Packers Fertilizer Co., Columbus, Ohio.											
4714	Number One, Independent Favorite	0.48	0.15	0.35	0.98	*0.80*	13.60	1.92	11.68	*11.00*	2.88	*3.00*
4715	Number Three, Corn, Wheat, Oats and Clover	0.33	0.16	0.46	0.95	*0.80*	11.70	1.04	10.66	*8.00*	3.16	*3.00*
4716	Number Five, Universal Crop	0.95	0.44	0.52	1.91	*1.65*	11.45	2.80	8.65	*8.00*	2.42	*2.00*
4717	Number Six, Truck & Tobacco Grower	0.62	0.37	0.35	1.34	*1.65*	11.80	2.16	9.64	*8.00*	3.10	*3.00*
4980	Number Six, Truck & Tobacco Grower	0.59	0.48	0.50	1.57	*1.65*	13.25	2.20	11.05	*8.00*	3.66	*3.00*
4718	Number Seven, Corn & Wheat Special	0.39	0.15	0.30	0.84	*0.80*	10.70	1.42	9.28	*8.00*	2.01	*2.00*
91546	Number Eight, Phosphate & Potash	......	......	......	......	......	11.50	0.46	11.01	*10.00*	1.25	*2.00*
4719	Special Sugar Beet Fertilizer	0.38	0.15	0.34	0.87	*0.80*	11.00	2.14	8.86	*8.00*	2.71	*3.00*
4981	Special Sugar Beet Fertilizer	0.35	0.14	0.44	0.93	*0.80*	12.90	1.86	11.04	*8.00*	3.38	*3.00*
	International Agricultural Corporation, Lockland, Ohio.											
	Corn, Wheat and Oats Special	......	......	......	......	*0.82*	......	......	......	*10.00*	......	*1.00*
91550	Eighteen Per Cent Acid Phosphate	......	......	......	......	......	20.50	0.26	20.24	*18.00*	......	......
91513	Garbage Tankage & Phosphate	0.08	0.14	0.30	0.52	*0.41*	15.95	1.21	14.74	*12.5*	......	......
4711	Lillie's Special No. 1	0.41	0.38	0.43	1.22	*0.80*	10.00	1.56	8.44	*8.00*	2.21	*2.00*
4712	Lillie's Special No. 2	0.78	0.58	0.37	1.73	*1.60*	10.00	1.38	8.62	*8.00*	3.06	*3.00*
91549	Lillie's Special No. 3	0.55	0.59	0.50	1.64	*1.60*	17.10	......	......	**15.00*	2.68	*2.00*
	Buffalo Brands.											
91547	Best Value	......	......	......	......	......	14.10	3.48	10.62	*10.00*	2.08	*2.00*
4710	Dissolved Phosphate	......	......	......	......	......	19.00	0.42	18.58	*14.00*	......	......
91548	Grain King	0.53	0.41	0.42	1.36	*1.20*	10.70	1.86	8.84	*8.00*	1.66	*1.50*
4942	Ideal Wheat and Corn	1.01	0.42	0.21	1.64	*1.60*	10.65	0.88	9.77	*9.00*	2.08	*2.00*
4713	One-Eight-Three	0.40	0.25	0.23	0.88	*0.80*	10.60	1.44	9.06	*8.00*	3.22	*3.00*
4781	One-Ten-Three	0.58	0.26	0.17	1.01	*0.80*	12.10	0.96	11.14	*10.00*	3.16	*3.00*
4779	Phosphate and Potash	......	......	......	......	......	14.60	0.56	14.04	*12.00*	1.97	*2.00*
4948	Vegetable and Potato	1.91	0.48	0.32	2.71	*2.50*	10.00	1.18	8.82	*8.00*	3.26	*3.00*
	The Jarecki Chemical Co., Sandusky, Ohio.											
4720	Clay Soil Special	1.05	0.62	0.24	1.91	*1.65*	14.55	1.66	12.89	*12.00*	......	......
4780	C. O. D. Phosphate	......	......	......	......	......	17.20	0.84	16.36	*14.00*	......	......
4721	Fish, Phosphate and Potash General Grower	1.01	0.36	0.34	1.71	*1.65*	9.90	1.00	8.90	*8.00*	3.06	*3.00*
4625	Fish, Phosphate & Potash Tobacco and Potato Food	0.48	0.20	0.20	0.88	*0.82*	9.10	0.62	8.48	*8.00*	3.00	*3.00*
4722	Lake Erie Guano with Phosphate and Potash	0.73	0.28	0.21	1.22	*1.25*	10.90	1.22	9.68	*9.00*	2.04	*2.00*
4810	Middle West Formula	0.27	0.36	0.24	0.87	*0.82*	13.45	1.16	12.29	*12.00*	0.90	*1.00*
4626	Number One Formula	0.46	0.22	0.20	0.88	*0.82*	11.15	0.70	10.45	*9.00*	1.42	*1.00*
91551	Pure Ground Bone	0.52	1.42	0.66	2.60	*2.50*	23.40	......	......	**20.00*	......	......
4943	Raw Bone & Phosphate Mixture	1.21	0.39	0.27	1.87	*1.65*	16.20	7.76	8.44	*8.00*	1.24	*1.00*

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*Total phosphoric acid.

ANALYSES OF COMMERCIAL FERTILIZERS FOR 1915, EXPRESSED IN PARTS IN ONE HUNDRED.—*Continued.*

Laboratory number.	Manufacturer and Trade Name.	Nitrogen.					Phosphoric Acid.				Potash.	
		As soluble.	As active insoluble organic.	As inactive insoluble organic.	Total found.	*Total guaranteed.*	Total.	Insoluble.	Available found.	*Available guaranteed.*	Total found.	*Total guaranteed.*
	The Jarecki Chemical Co.—Con.											
4944	Special Sugar Beet Grower	0.35	0.28	0.21	0.84	*0.82*	10.40	0.78	9.62	*8.00*	**2.70**	*3.00*
4982	Special Sugar Beet Grower	0.54	0.13	0.20	0.87	*0.82*	10.10	1.44	9.66	*8.00*	2.96	*3.00*
4627	Super Phosphate & Potash						14.05	0.92	13.13	*12.00*	1.93	*2.00*
	The Kalamazoo Rendering & Fertilizer Co., Kalamazoo, Mich.											
4782	Kalferco	0.52	1.02	0.41	1.95	*1.65*	13.65	8.45	**5.20**	*8.00*	0.89	*1.00*
4783	Kazoo	0.86	0.85	0.61	2.32	*1.50*	11.45	6.25	**5.20**	*6.00*	2.84	*3.00*
	Natural Guano Company Aurora, Ill.											
4724	"Sheep's Head" Pulverized Sheep Manure	0.53	0.44	1.32	2.29	*2.25*	1.45	0.20	1.25	*1.00*	1.84	*1.50*
4784	"Sheep's Head" Pulverized Sheep Manure	0.54	0.47	1.32	2.33	*2.25*	1.50	0.12	1.38	*1.00*	1.96	*1.50*
	Nitrate Agencies Company, Columbus, Ohio.											
101512	Acid Phosphate 16%						18.00	0.40	17.60	*16.00*		
4945	Genuine Peruvian Guano	8.65	2.48	0.09	11.22	*10.66*	13.85	2.85	11.00	*10.00*	2.92	*2.00*
4949	Genuine Peruvian Guano	7.83	2.44	0.25	**10.52**	*10.66*	13.55	2.43	11.12	*10.00*	2.80	*2.00*
4725	Nitrate of Soda	15.40			15.40	*15.00*						
	The Ohio Standard Chemical Co., Toledo, Ohio.											
4815	Standard G	1.03	0.23	0.31	1.57	*1.65*	9.80	1.58	8.22	*8.00*	2.14	*2.00*
	Standard Q					*0.82*				*8.00*		*1.00*
	The Packer's Fertilizer Co., Cincinnati, Ohio.											
4726	Acidulated Phosphate						16.90	1.28	15.62	*14.00*		
101513	Ammoniated Phosphate	0.54	0.17	0.31	1.02	*0.82*	11.90	1.00	10.90	*9.00*	1.03	*1.00*
4628	Animal Tankage Phosphate & Potash	0.38	0.35	0.20	0.93	*0.82*	10.15	0.80	9.35	*8.00*	3.06	*3.00*
101515	Bone Meal	0.82	1.07	0.59	2.48	*2.47*	25.95			**20.00*		
4785	Potato, Tobacco & Truck Manure	0.88	0.30	0.17	**1.35**	*1.65*	10.20	0.92	9.28	*8.00*	3.00	*3.00*
4983	Potato, Tobacco & Truck Manure	1.03	0.38	0.36	1.77	*1.65*	9.40	1.10	8.30	*8.00*	3.38	*3.00*

101514	Pure Bone with Phosphate & Potash	0.57	0.72	0.50	1.79	*1.65*	16.30	7.44	8.86	*8.00*	1.26	*1.00*
101516	Quality Brand	0.59	0.29	0.11	0.99	*0.82*	14.00	1.48	12.52	*12.00*	1.30	*1.00*
4786	Super Phosphate & Potash						13.30	0.84	12.46	*12.00*	1.98	*2.00*
4816	"Sweepstakes"	0.78	0.26	0.27	1.31	*1.23*	10.40	0.64	9.76	*9.00*	2.22	*2.00*
	The Pulverized Manure Co., Chicago, Ill.											
4728	Wizard Brand Cattle Manure	0.49	0.45	1.18	2.12	*1.80*	1.85	0.06	1.79	*1.00*	2.75	*1.00*
4729	Wizard Brand Sheep Manure	0.96	0.28	0.43	**1.67**	*1.80*	1.05		1.05	*1.00*	1.22	*1.00*
	The Queen City Fertilizer Co., Cincinnati, Ohio.											
101517	Special Sugar Beet Grower	0.48	0.31	0.28	1.07	*0.82*	10.50	1.00	9.50	*8.00*	2.82	*3.00*
	Rasin-Monumental Co., Cincinnati, Ohio.											
4732	Acid & Potash King						19.40	2.44	16.96	*15.00*	2.48	*2.00*
4730	16% Acid Phosphate						21.20	2.28	18.92	*16.00*		
101518	18% Acid Phosphate						19.30	0.20	19.10	*18.00*		
101519	20% Acid Phosphate						22.30	0.24	22.06	*20.00*		
4731	10-2 Acid & Potash						22.20	1.61	10.59	*10.00*	2.46	*2.00*
101520	18-2 Acid Phosphate & Potash						20.10	1.00	19.10	*18.00*	2.06	*2.00*
91552	Bone Meal Acid & Potash Mixture	0.32	0.48	0.25	1.05	*0.82*	20.90	9.32	11.58	*9.00*	3.88	*3.00*
91553	Complete Fertilizer	1.13	0.32	0.36	1.81	*1.64*	11.28	1.54	9.74	*8.00*	2.50	*2.00*
101521	Empire Guano	0.85	0.15	0.09	1.09	*0.82*	16.70	1.08	15.62	*14.00*	2.04	*2.00*
4733	Gold Standard Guano	0.57	0.16	0.19	0.92	*0.82*	13.35	2.08	11.27	*10.00*	3.22	*3.00*
4734	Little Giant Guano	0.53	0.15	0.27	0.95	*0.82*	11.25	2.12	9.13	*8.00*	3.28	*3.00*
4811	Monumental Bean Grower	1.24	0.23	0.26	1.73	*1.64*	11.40	2.28	9.12	*8.00*	3.11	*3.00*
101522	National Wheat Fertilizer	0.28	0.08	0.08	0.44	*0.41*	14.10	1.56	12.54	*12.00*	2.90	*3.00*
4735	Reliable Wheat & Corn Fertilizer	0.62	0.15	0.28	1.05	*0.82*	12.60	2.40	10.20	*8.00*	2.06	*2.00*
4812	Reliable Wheat & Corn Fertilizer	0.58	0.16	0.23	0.97	*0.82*	11.25	2.06	9.19	*8.00*	2.96	*2.00*
101523	Standard Wheat & Corn Grower	0.74	0.11	0.11	0.96	*0.82*	13.50	2.04	11.46	*11.00*	3.00	*3.00*
	F. S. Royster Guano Co., Baltimore, Md.											
4789	Brilliant Compound	0.63	0.26	0.13	1.02	*0.82*	12.70	1.62	11.08	*11.00*	2.40	*2.00*
4790	Cloverdale Grain & Grass Grower						11.75	1.06	10.69	*10.00*	2.06	*2.00*
1169	Cuckoo Crop Grower	0.52	0.44	0.05	1.01	*0.82*	9.66	0.86	8.80	*8.00*	1.11	*1.00*
4791	Dreadnaught Fertilizer	1.14	0.42	0.17	1.73	*1.65*	10.45	2.08	8.37	*8.00*	2.06	*2.00*
4792	Eldorado Compound	1.31	0.28	0.14	1.73	*1.65*	12.55	1.62	10.93	*10.00*	3.12	*3.00*
4793	Fish, Flesh & Fowl	1.10	0.39	0.19	1.68	*1.65*	10.35	2.02	8.33	*8.00*	3.30	*3.00*
4787	14% Acid Phosphate						17.60	1.50	16.10	*14.00*		
4788	H. G. 16% Acid Phosphate						18.90	1.16	17.74	*16.00*		
4794	Harmony Compound						14.60	1.28	13.32	*12.00*	1.82	*2.00*

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*Total phosphoric acid.

ANALYSES OF COMMERCIAL FERTILIZERS FOR 1915, EXPRESSED IN PARTS IN ONE HUNDRED.—*Continued.*

Laboratory number.	Manufacturer and Trade Name.	Nitrogen.					Phosphoric Acid.				Potash.	
		As soluble.	As active insoluble organic.	As inactive insoluble organic.	Total found.	*Total guaranteed.*	Total.	Insoluble.	Available found.	*Available guaranteed.*	Total found.	*Total guaranteed.*
	F. S. Royster Guano Co.—Con.											
91532	Harmony Compound						13.95	1.40	12.55	*12.00*	1.92	*2.00*
4795	Seeding Down Special Fertilizer	0.65	0.25	0.08	0.98	*0.82*	11.65	1.60	10.05	*9.00*	2.90	*3.00*
4796	Wheat, Oats and Barley Fertilizer	0.57	0.18	0.11	0.86	*0.82*	9.57	1.82	**7.75**	*8.00*	1.85	*2.00*
4984	Wheat, Oats and Barley Fertilizer	0.47	0.32	0.14	0.93	*0.82*	10.15	1.22	8.93	*8.00*	2.70	*2.00*
91518	Wonder Worker Guano	0.51	0.33	0.14	0.97	*0.82*	9.50	0.90	8.60	*8.00*	3.38	*3.00*
	The Smith Agricultural Chemical Co., Columbus, Ohio.											
4631	Climax Phosphate						16.50	0.62	15.88	*14.00*	1.87	*2.00*
4634	Peerless Phosphate & Potash	0.51	0.15	0.27	0.93	*0.80*	10.35	0.86	9.49	*9.00*	1.10	*1.00*
91525	Peerless Phosphate & Potash	0.59	0.18	0.25	1.02	*0.80*	10.75	1.70	9.05	*9.00*	1.54	*1.00*
4636	Vegetable Grower	1.74	0.41	0.50	2.65	*2.40*	10.25	0.98	9.27	*8.00*	3.30	*3.00*
4629	Ammoniated Phosphate & Potash	0.59	0.16	0.34	1.09	*0.82*	11.10	1.02	9.08	*9.00*	3.06	*3.00*
4630	Smiths Best	1.21	0.20	0.23	1.64	*1.64*	14.67	0.50	14.17	*12.00*	2.80	*2.00*
4632	Corn, Oats & Wheat Fertilizer	1.18	0.30	0.29	1.77	*1.64*	10.50	1.12	9.38	*8.00*	2.12	*2.00*
4633	Crop Producer	1.23	0.20	0.44	1.87	*1.64*	10.80	0.86	9.94	*9.00*	3.44	*3.00*
91554	16% Acid Phosphate						17.85	0.70	17.15	*16.00*		
91526	Star Phosphate						12.75	0.42	12.33	*11.00*	0.96	*1.00*
4635	Soluble Phosphate & Potash						13.20	0.76	12.44	*10.00*	2.02	*2.00*
4637	Wheat Maker Seeding Down	0.64	0.15	0.30	1.09	*0.82*	9.90	1.20	8.70	*8.00*	2.18	*2.00*
	Elmer D. Smith & Co., Adrian, Mich.											
4736	Chrysaline	13.32			**13.32**	*16.80*	27.40		27.40	*24.40*	20.72	*19.80*
91555	Chrysaline	13.23			**13.23**	*16.80*	28.00		28.00	*24.40*	24.48	*19.80*
	Speidel & Swartz, Grand Haven, Mich.											
4797	Celery Hustler	2.06	2.93	1.21	6.20	*6.00*	4.95	1.06	3.89	*3.25*	**0.12**	*1.06*

	The J. L. & H. Stadler Rendering & Fertilizer Co., Cleveland, Ohio.											
4638	Acid Phosphate	....	....	....	....	....	17.20	2.02	15.18	*14.00*	....	....
4639	Acid Phosphate & Potash	....	....	....	....	....	16.25	1.78	14.47	*13.00*	**1.74**	*2.00*
4985	Acid Phosphate & Potash	....	....	....	....	....	16.50	3.73	**12.77**	*13.00*	**1.42**	*2.00*
4640	Acidulated Tankage	1.03	0.26	0.32	1.61	*1.60*	15.45	1.62	13.83	*12.00*	....	....
4641	Corn & Wheat Special	0.38	0.26	0.36	1.00	*0.80*	10.85	2.38	8.47	*8.00*	3.36	*3.00*
91556	General Crop Grower	0.89	0.37	0.69	1.95	*1.60*	13.60	2.84	10.76	*10.00*	1.24	*1.00*
4642	Grain Grower	0.82	0.45	0.70	1.97	*1.60*	11.55	2.90	8.65	*8.00*	2.34	*2.00*
91557	Harvest King	0.33	0.29	0.48	1.10	*0.80*	12.15	1.28	10.87	*9.00*	1.20	*1.00*
4643	Oats & Corn Grower	0.35	0.22	0.33	0.90	*0.80*	10.25	1.58	8.67	*8.00*	1.88	*2.00*
91558	Pure Bone Meal	1.09	1.12	0.92	3.13	*2.80*	21.20	....	....	**20.00*	....	....
4644	Valley Phosphate	0.86	0.58	0.69	2.13	*2.00*	13.65	4.24	9.41	*9.23*	3.08	*3.00*
4645	Vegetable & Grain Grower	0.63	0.40	0.58	1.61	*1.20*	11.85	1.84	13.01	*12.00*	2.08	*2.00*
	G. B. Stock Xylite Grease & Oil Co., Port Huron, Mich.											
4798	Xylite	2.37	2.28	1.17	5.82	*4.78*	14.65	7.23	7.42	*7.25*	....	....
	Swift & Company, Chicago, Ill.											
4738	Bean & Grain Grower	0.29	0.28	0.27	0.84	*0.82*	9.30	1.26	8.04	*8.00*	2.89	*3.00*
91512	Bone Meal & Phosphate	0.24	0.45	0.25	0.94	*0.82*	23.65	8.87	14.78	*13.00*	....	....
91529	Champion Wheat & Corn Grower	0.75	0.32	0.65	1.72	*1.65*	14.55	2.32	12.23	*12.00*	2.08	*2.00*
4813	Champion Wheat & Corn Grower	0.93	0.30	0.28	**1.53**	*1.65*	14.20	1.08	13.12	*12.00*	1.83	*2.00*
4739	Complete Fertilizer	0.42	0.21	0.30	1.01	*0.82*	9.37	1.38	7.99	*8.00*	0.87	*1.00*
4737	Diamond "A" Vegetable & Beet Grower	1.38	0.39	0.59	**2.36**	*2.47*	10.30	1.34	8.96	*8.00*	3.00	*3.00*
4986	Diamond "A" Vegetable & Beet Grower	1.23	0.41	0.84	2.48	*2.47*	8.98	1.14	7.84	*8.00*	3.73	*3.00*
4987	Diamond "A" Vegetable & Beet Grower	1.38	0.41	0.71	2.50	*2.47*	8.93	1.24	**7.69**	*8.00*	3.20	*3.00*
4648	Diamond "K" Grain Grower	0.29	0.25	0.37	0.91	*0.82*	13.45	1.04	12.41	*12.00*	1.08	*1.00*
91559	Diamond "I" Grain Grower	0.38	0.16	0.38	0.92	*0.82*	10.95	0.94	10.01	*10.00*	1.91	*2.00*
4742	Diamond "L" Grain Grower	0.73	0.33	0.33	**1.39**	*1.65*	13.30	0.66	12.64	*12.00*	0.98	*1.00*
4649	Diamond "N" Grain Grower	0.72	0.36	0.57	1.59	*1.65*	10.75	1.34	9.41	*9.00*	1.06	*1.00*
4990	Diamond "N" Grain Grower	0.64	0.30	0.61	1.55	*1.65*	11.70	1.64	10.06	*9.00*	1.05	*1.00*
4991	Diamond "N" Grain Grower	0.65	0.37	0.55	1.57	*1.65*	10.55	1.16	9.39	*9.00*	1.04	*1.00*
101526	Diamond "S" Hay & Silage Fertilizer	1.78	0.50	0.81	3.09	*2.47*	11.30	1.56	9.74	*8.00*	0.83	*0.33*
9158	Diamond "S" Phosphate	....	....	....	....	....	10.83	0.24	10.59	*10.00*	....	....
101527	Diamond "U" Fruit & Vegetable Grower	2.02	1.03	0.69	3.74	*3.29*	11.30	1.56	9.74	*8.00*	3.79	*3.00*
4748	Diamond "W" Vegetable Grower	0.57	0.44	0.62	1.63	*1.65*	10.45	1.52	8.93	*8.00*	3.20	*3.00*

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*Total phosphoric acid.

ANALYSES OF COMMERCIAL FERTILIZERS FOR 1915, EXPRESSED IN PARTS IN ONE HUNDRED.—*Concluded.*

Laboratory number.	Manufacturer and Trade Name.	Nitrogen.					Phosphoric Acid.				Potash.	
		As soluble.	As active insoluble organic.	As inactive insoluble organic.	Total found.	*Total guaranteed.*	Total.	Insoluble.	Available found.	*Available guaranteed.*	Total found.	*Total guaranteed.*
	Swift & Company.—Con.											
4646	Dissolved Animal Bone with Potash	0.48	0.43	0.27	1.18	*1.23*	19.25	5.80	13.45	*13.00*	1.49	*1.50*
4988	Dissolved Animal Bone with Potash	0.44	0.47	0.30	1.21	*1.23*	20.30	5.90	14.40	*13.00*	1.72	*1.50*
4989	Dissolved Animal Bone with Potash	0.54	0.44	0.28	1.26	*1.23*	17.74	5.65	**12.09**	*13.00*	1.58	*1.50*
91528	Garden City Phosphate	......	......	......	......	......	14.95	0.36	14.59	*14.00*	......	......
11156	High Grade Acid Phosphate	......	......	......	......	......	18.50	1.04	17.46	*16.00*	......	......
91527	Muck Soil Fertilizer	0.45	0.14	0.44	1.03	*0.82*	12.35	1.06	**11.29**	*12.00*	3.88	*3.00*
4743	Muck Soil Fertilizer	0.33	0.23	0.31	0.87	*0.82*	12.95	0.58	12.37	*12.00*	3.40	*3.00*
101525	Nitrate of Soda	15.63	......	......	15.63	*14.81*	......	......	......	......	......	......
4745	Pulverized Sheep Manure	0.41	0.31	0.82	**1.54**	*1.65*	1.65	......	1.65	**1.00*	3.36	*1.50*
4992	Pulverized Sheep Manure	0.28	0.42	1.04	1.74	*1.65*	1.26	0.14	1.12	**1.00*	2.64	*1.50*
9156	Pure Bone Meal	0.55	1.52	0.56	2.63	*2.47*	24.20	......	......	**24.00*	......	......
101524	Pure Ground Dried Blood	1.04	10.15	2.82	14.01	*13.17*	......	......	......	......	......	......
4799	Pure Lawn Fertilizer	1.40	0.58	0.42	2.40	*2.47*	9.70	1.62	8.08	*8.00*	3.18	*3.00*
91530	Special Grain Grower	0.76	0.28	0.68	1.72	*1.65*	11.40	1.77	**9.63**	*10.00*	2.03	*2.00*
4650	Superphosphate	0.76	0.35	0.53	1.61	*1.65*	9.85	1.44	8.41	*8.00*	2.16	*2.00*
4647	12-1 Brand	......	......	......	......	......	13.70	0.66	13.04	*12.00*	**0.73**	*1.00*
4993	12-1 Brand	......	......	......	......	......	13.85	0.58	13.27	*12.00*	0.90	*1.00*
4994	12-1 Brand	......	......	......	......	......	12.90	0.34	12.56	*12.00*	**0.79**	*1.00*
4800	14-1 Brand	......	......	......	......	......	14.50	0.52	13.98	*14.00*	1.12	*1.00*
	Pioneer Brands.											
101528	Black Soil Special	0.39	0.44	0.34	1.17	*0.82*	14.40	0.88	13.52	*12.00*	3.51	*3.00*
4727	Dissolved Animal Bone with Potash	0.51	0.44	0.24	1.19	*1.23*	19.60	6.32	13.28	*13.00*	1.45	*1.50*
11157	General Crop Grower	0.65	0.30	0.72	1.67	*1.65*	9.85	0.60	9.25	*8.00*	2.04	*2.00*
4801	No. 1 Grain Fertilizer	0.64	0.36	0.61	1.61	*1.65*	10.35	1.22	9.13	*9.00*	1.10	*1.00*
4802	No. 2 Grain Fertilizer	0.33	0.25	0.29	0.87	*0.82*	13.80	0.86	12.94	*12.00*	**0.72**	*1.00*
4803	No. 3 Vegetable & Fruit Fertilizer	2.18	0.32	0.18	2.68	*2.47*	9.80	1.62	8.18	*8.00*	2.93	*3.00*
91560	No. 4 Grain Grower	0.33	0.15	0.44	0.92	*0.82*	9.75	0.98	8.77	*8.00*	1.06	*1.00*

	The Toledo Seed & Oil Co., Toledo, Ohio.											
4938	Owl Brand Fertilizer	0.84	1.81	1.80	4.45	*3.80*	0.55	.....	.....	*0.25*	0.92	*0.25*
91531	Owl Brand Fertilizer	0.54	2.13	1.76	4.63	*3.80*	0.45	0.10	0.35	*0.25*	0.86	*0.25*
	Tuscorara Fertilizer Co., Chicago, Ill.											
101529	Acid Phosphate	.....	.....	.....	.....	.....	14.80	0.05	14.75	*14.00*	.....	.....
91561	Phosphate & Potash	.....	.....	.....	.....	.....	11.25	0.62	10.63	*10.00*	2.24	*2.00*
4804	Standard	0.63	0.72	0.40	1.75	*1.65*	11.15	2.92	8.23	*8.00*	1.89	*2.00*
4749	Wheat, Corn & Bean Grower	0.34	0.40	0.24	0.98	*0.82*	9.55	1.28	8.27	*8.00*	**1.76**	*2.00*
101530	12-2 Fertilizer	.....	.....	.....	.....	.....	13.70	0.40	13.30	*12.00*	2.12	*2.00*
9157	1-9-1 Fertilizer	0.58	0.27	0.26	1.11	*0.82*	10.70	1.42	9.28	*9.00*	0.99	*1.00*
4805	2-8-3 Fertilizer	0.70	0.78	0.49	1.97	*1.65*	11.15	2.98	8.17	*8.00*	2.82	*3.00*
	The Wuichet Fertilizer Co., Dayton, Ohio.											
101531	Ammonia Special	1.17	0.44	0.35	**1.91**	*2.40*	18.85	5.84	13.01	*12.00*	.....	.....
4807	Dayton Fertilizer	0.92	0.70	0.32	1.94	*1.60*	15.32	5.61	9.72	*10.00*	3.56	*3.00*
4808	Miami Fertilizer	0.57	0.61	0.36	**1.24**	*1.60*	13.10	4.83	8.27	*9.00*	2.90	*3.00*
4995	Miami Fertilizer	0.47	0.23	0.22	**0.92**	*1.60*	13.70	3.97	9.73	*9.00*	**2.48**	*3.00*
4996	Miami Fertilizer	0.49	0.28	0.38	**1.15**	*1.60*	13.03	4.42	**8.61**	*9.00*	2.96	*3.00*
91562	Raw Bone & Phosphate	0.60	0.59	0.67	1.86	*1.60*	14.65	5.54	9.11	*8.00*	1.74	*1.50*
9152	Ruby	0.22	0.22	0.36	0.80	*0.80*	12.98	3.69	9.29	*9.00*	1.00	*1.00*
9154	16% Phosphate	.....	.....	.....	.....	.....	21.08	4.58	16.50	*16.00*	.....	.....
4809	Spot Cash Fertilizer	1.04	0.51	0.32	1.87	*1.60*	12.85	3.68	9.17	*9.00*	2.20	*2.00*
9151	Spot Cash Fertilizer	0.66	0.48	0.58	1.72	*1.60*	13.80	4.72	9.08	*9.00*	2.28	*2.00*

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*Total phosphoric acid.

FOREWORD.

November 30, 1915.

The summer just passed has witnessed an outbreak of the work of the bean-maggot such as has never before been experienced in Michigan. To partially compensate for the serious losses sustained, however, the outbreak has offered an opportunity for gathering data of importance which seems to justify the publication of this circular. The observations made by Mr. Don B. Whelan are offered, therefore, in the hope that advantage may be taken of them during the coming season.

Respectfully submitted,
R. H. PETTIT,
Entomologist of Experiment Station.

THE BEAN-MAGGOT IN 1915.

Circular No. 28.

BY DON B. WHELAN.

The "bean maggot" has appeared in Michigan from time to time, but visits heretofore have been scattered over quite a large area and the damage has been comparatively slight up to the present season. This pest also bears the name "seed corn maggot," having long been known as being destructive to seed corn. It is recorded in connection with quite a variety of host-plants, including beans, peas, corn, cabbage, turnips, potatoes and some weeds besides other cultivated plants. Its work in the past has often been confused with both that of the "onion maggot" and "cabbage maggot."

As in the case of the last two species, the adult of the bean-maggot is a fly, in form and color very similar to the house-fly but differing in that it is somewhat smaller. This winged fly usually lays its eggs on the stems of plants just coming through the soil or on decaying vegetable matter, which appears to be its favorite breeding place. The eggs hatch into maggots which scrape channels and tunnels in growing plants and ruin them. There is every reason to believe that two or more generations develop during the growing season.

It has long been known that decaying vegetation furnishes a breeding place for this pest, although the opportunity has never before presented itself to bring this fact out so favorably. During the year 1915, serious damage from the bean-maggot was reported from Huron, Sanilac, Tuscola, Saginaw, Gratiot, Eaton and Berrien counties. The beginning of the trouble occurred near Charlotte when a farmer first noticed the work of this insect on a large field of beans, on June 14th, four days after the seed was planted and before the beans had pushed their way above the ground. The samples brought to the Entomological laboratory, including both beans and growing stems, were perforated and badly injured by dirty-white maggots, about a quarter of an inch in length. About sixty per cent. of the plants were killed before appearing above ground. This case showed clearly that the maggots were in the soil before the beans were planted and that they merely transferred their attention from the fresh manure which had recently been plowed under, to the beans, (the land having previously been a vineyard). This explanation appealed immediately to Professor Pettit, who turned the problem over to the writer for thorough investigation. Examination of a series of bean fields, beginning on July 1st, revealed many cases of a quite similar nature, from which it appears that the maggots are sometimes found in fresh manure and also in clover sod and in the rotting stems of clover. Furthermore, it appears that while beans were apt to suffer when planted on freshly turned clover sod, especially if recently fertilized with undecomposed manure, they stood a much better chance of escape if the field was prepared early in the season and the maggots given a chance to develop and disappear before the beans were planted. To illustrate this point the following cases are cited:

Near Akron, Tuscola county, a field of five acres of beans planted on clover sod, was injured to the extent of about fifty per cent. After the damage was first noticed on June 22d, two acres of this field were plowed and replanted on the 28th. The second planting was slightly injured by the maggots but not nearly as badly as the first crop. Another field of beans located directly across the road had been planted at the same time, but on an overturned timothy sod without an application of stable manure; in this case no injury from maggots was shown.

In another instance in this same locality, a field consisting of clover sod was heavily manured before plowing and fitting. This field consisted of nine acres of which six acres was sowed to beans, two and one-half acres to corn and one-half acre to potatoes. The beans, which were planted on June 14th, were damaged, resulting in about an eighty per cent loss, making it necessary to plow and reseed with millet. The corn which was planted about June 5th showed no damage.

Another case which shows nicely the effect of a combination of clover sod and manure, occurred near Middleton on a Gratiot county farm. One area which had been in clover the previous year and early spring had hogs penned in the middle of the field where they remained until June 20th. The field was planted to beans on June 23d without the use of fertilizers. Injury from the bean-maggot was shown only where the pigs had been. On this farm the other field, which had previously been in oats and which received practically the same treatment as in the first case, showed no injury.

The following illustration is from a forty-five acre bean field on a farm near Bad Axe in Huron county. In this field, which had formerly been a pasture lot, the higher bare spots received stable manure before plowing and these were the only portions infested with maggots.

The preceding illustrations are cited as examples of the many cases that were examined during the season, all of which point to the same conclusion.

In summing up, it appears that the best way to combat the bean-maggot is by cultural methods. As the maggot breeds in manure and other decaying material, as well as in exposed clover roots moistened by rains, it is necessary to prepare the ground early in the season to allow the maggots time to disappear before the beans are sowed. Furthermore, it seems that plants from more vigorous seed suffered less injury than those of poorer vitality.

Land which is in clover, or which is covered with manure, should be plowed early and prepared so that the soil will be in good condition.

Commercial fertilizers may be substituted for barnyard manure when the necessity for late fitting of the soil demands it, and repeated harrowing and perhaps rolling, especially when the ground is light in texture, seem to aid.

SUMMARY.

To Circular No. 29.

(1) Infectious abortion in cattle is widely distributed throughout the state.

(2) We know very little about many features of the disease.

(3) There is no entirely satisfactory and easily applied method of controlling the disease known to us.

(4) A common way in which the disease is introduced into the herd is through the purchase of an affected female animal.

(5) Food or water soiled by the discharges of an affected animal may convey the disease to healthy animals.

(6) The bull may convey the infection from one animal to another.

(7) Not all abortions are known to be infectious.

(8) There are no known symptoms by which we can always differentiate between infectious abortion and abortion due to other causes.

(9) Through a blood examination we are apparently able to determine whether the abortus bacillus has affected the animals of a herd.

(10) The blood examination will not determine whether an animal will abort as all affected animals do not abort.

(11) Sterility frequently follows abortion. If this can be prevented by local treatment subsequent pregnancies will usually terminate normally.

(12) In the hands of an experienced operator sterility may yield to special treatment.

(13) An animal may harbor the infection for years without aborting. Such animals are dangerous to susceptible animals in the herd.

(14) We have not been able uniformly to prevent abortion by the use of bacterial vaccines.

(15) Carbolic acid is the principal constituent of some of the most widely advertised so-called abortion cures, but our experience with carbolic acid has not been entirely satisfactory.

(16) Methylene blue has been recommended. We have not had sufficient experience with this drug to justify us in recommending it, but our knowledge of it does not warrant its recommendation.

(17) The plan we suggest is one of local treatment of the affected cow, disinfection and sanitation.

(18) Parturient cows in infected herds, whether aborting or not, should be isolated from the herd and kept isolated until all discharges have ceased.

(19) The afterbirth and litter contaminated with the discharges should be burned.

(20) The cow should receive irrigations of some mild non-toxic antiseptic until the discharges have ceased.

(21) The external parts of the cow should be cleaned daily.

(22) In case of abortion the animal should not be bred until all discharges have ceased.

(23) At the time of service the sheath of the bull should be irrigated and the inferior abdominal surface of the bull should be cleaned before and after service.

(24) A 1 to 1000 solution of potassium permanganate, ½ of 1 per cent. compound solution of iodine, a ¾ of 1 per cent. solution of compound solution of cresol or sour whey may be used for uterine and vaginal injections.

(25) Drastic or improper treatment of the genital organs of a cow is more injurious than no treatment at all.

INFECTIOUS ABORTION IN CATTLE.

Circular No. 29.

INTRODUCTION.

In Michigan we consider infectious abortion one of the three infectious diseases (hog cholera, tuberculosis, infectious abortion) of greatest importance and gravest danger to the industry of animal husbandry in this section of the country. Our experiences gained by conversation, correspondence and personal inspections, indicate that infectious abortion is distributed throughout the state in the pure bred herds especially, but also in herds without breeding. It is found in public institutional and in private herds where sanitary conditions are nearly ideal and in herds kept under very insanitary conditions. Its greater prevalence in pure bred herds is not due to their breeding, but to the greater and more widespread traffic in such animals.

There is a popular and urgent demand from all parts of the state for information relative to this disease and in an effort to satisfy this demand we are presenting the facts concerning the disease as they now appear to us. We must confess an ignorance of many features of the disease and an inability to outline any entirely satisfactory plan of control. Many European and American investigators are studying the various phases of the disease with the one object of discovering some means of control. However, knowledge of a definite and practical nature which can be effectively applied must be expected to come slowly. From a careful study of all the available literature and from our own observations we are presenting that which to us appears the best.

MEANS OF DISSEMINATION.

Affected cows. A common way in which the disease is introduced into the herd is through the purchase of an affected female animal. She may be an apparently healthy cow, either with calf or non-pregnant. If affected, such a cow may become a source of infection at the time she calves and remain so until the uterus is free of the disease or until the cow again becomes pregnant. During pregnancy we do not know whether an affected animal eliminates the infectious organism through the genital passages, but we are inclined to believe they do not. Just how long an affected cow will continue to discharge from the vagina the infectious material after an abortion or a normal parturition we do not know, but it is known that the cow may excrete the abortion germ for years in the milk.

The bull. The bull may carry the infection from one animal to another. The bull does not necessarily become affected with the disease, but through contamination of the penis and sheath with the discharges of an affected cow he is able to convey the disease to other animals.

Contaminated food and water. Food or water soiled by the discharges of an animal that has aborted or of an affected animal that has calved normally may convey the disease to a healthy animal. Calves born of such animals may also spread the disease germs with their feces.

DIAGNOSIS.

Infectious and non-infectious. As to the diagnosis of infectious abortion it may be said that not all abortions are known to be infectious. Various causes may produce abortion. It is of the utmost importance, when an animal aborts to determine if possible whether the abortion is infectious. There are no symptoms by which this fact can be determined with accuracy although the history of the case may be helpful in making a diagnosis.

Blood tests. Through a blood examination the nature of the abortion or the presence of infection in the herd may be determined with a fair degree of accuracy. We shall be glad to make this examination without cost for anyone who will furnish us with about one ounce of blood from each animal to be examined. When abortion occurs in a herd it is suggested that every animal in the herd be tested. It is a fairly easy operation to draw the blood from the jugular vein. Any qualified veterinarian, with about two men to assist in holding the animals should be able to draw 20 to 30 samples in an hour. This laboratory will furnish sterile bottles for the samples to anyone requesting them and stating the number to be tested.

Limitations of blood tests. Let it be understood that we cannot determine by this test whether an animal will abort. Not all affected animals will abort. *Abortion is a symptom of a disease and like most symptoms is not constant.* The test may serve to determine the extent of infection in a herd but not the number of animals that will abort. The test indicates that an animal may harbor the infection for years without aborting. If this is true it may be necessary to handle such an animal with the same care to prevent spreading of the disease as though abortion had occurred.

Sterility. One of the serious aspects of this disease is the frequency with which sterility follows abortion. If we can prevent this by local treatment of the genital organs, following pregnancies will, in the majority of cases, terminate normally.

Carriers. We have reason to believe that an animal may harbor the infection for years and, while able to tolerate the presence of the abortion germ, she may be a constant menace to susceptible animals in the herd. Again there are animals in affected herds that become infected but may not abort. Such animals, and those that have apparently recovered, since they do not continue to abort, are to be considered dangerous animals in the herd from a sanitary point of view, and ones presenting great difficulties in the control of the disease. In carrying out any plan aimed at the eradication of the disease, such animals should be handled in a manner similar to that employed with aborting animals.

CONTROL OF THE DISEASE.

Unfortunately it is not possible at this time to suggest an entirely effective and satisfactory plan of controlling this disease.

Bacterial vaccines. In our experimental work with the use of bacterins on pregnant animals and with the use of living cultures of the abortus bacillus on open females we have found that the results have not been encouraging. So far we have been unable constantly to prevent abortion by the use of bacterins on pregnant animals and we are yet uncertain as to the beneficial, or even injurious effects, resulting from the use of living cultures on open females. Others have reported similar experiences.

Carbolic acid. There are a number of so-called abortion cures on the market, none of which we can recommend. The principal constituent of some of the most widely advertised abortion cures is carbolic acid. This drug has been used in the treatment of infectious abortion for many years and is recommended by some but our experience with it in this state has not been entirely satisfactory.

Methylene blue. Recently methylene blue has been recommended. We have had little opportunity to observe the effects of this drug on pregnant animals in affected herds, however we have seen animals abort on the methylene blue treatment and we have had unfavorable reports from dairymen who have used the drug. Owing to the limited data at hand as to its merits we do not feel justified in recommending it. For the benefit of those who wish to try methylene blue we quote from a personal communication from Dr. Rich of the Vermont Station. "I would say that the interrupted method of giving the methylene blue advised in our preliminary bulletin did not prove as satisfactory as our former method of giving it constantly for from four to six weeks, so for nearly a year we have advised giving about a half ounce daily for at least four or five weeks." He would revise the directions to read as follows: "The opinion of the writer to date is that the treatment should begin early in pregnancy; that 10 to 20 grams (⅓ to ⅔ oz.) should be given on silage or moistened grain feed, each day, for four or five weeks." To Dr. Rich is due the credit for having first suggested the use of this drug for infectious abortion in cattle.

Acquired immunity. Occasionally we hear of apparently favorable results from the use of various remedies, but we are convinced that in the majority of cases, the apparent beneficial results are explained by a possible tolerance to the disease which may follow after a previous abortion. Many cows abort only once or twice, subsequent pregnances terminating normally.

Sale of aborting animals. Frequently one is advised to sell for slaughter the aborting animals. The disease cannot be controlled in this way since all affected animals do not abort. An animal affected with the disease but not aborting may be as great a source of danger to other nonaffected animals as is one aborting.

Suggested plan. In the light of our present knowledge of the disease the only plan that we suggest for the control of the disease in affected herds, that offers any hope of reward, is one of local treatment of the affected cow, disinfection and sanitation.

Isolation and treatment of parturient cows. Each case of parturition, whether premature or normal, should be separated from the herd and kept isolated until all uterine discharges have ceased. The afterbirth and all litter contaminated with the discharges should be burned or buried deeply. Should the cow not clean within twenty-four hours after delivery, an attempt should be made by a *qualified* person to remove the afterbirth. The floor of the stable or maternity stall and gutter should be disinfected. Such a cow should receive once daily, uterine irrigations of some mild, non-toxic antiseptic until the uterus can no longer be entered by ordinary methods and then vaginal injections once every two or three days or oftener until the discharges have ceased. The external parts that are likely to become soiled with the discharges should be cleaned with a disinfectant. Not until the discharges have ceased should the animal be returned to the herd and if the case is an abortion, breeding should be deferred until there is reason to feel that no infection of the reproductive organs exists.

Non-breeders and persistent cases. Recently there has been introduced into this country, largely through the efforts of Prof. W. L. Williams of Cornell, a more or less systematic plan of procedure in the handling of cases that persistently fail to breed or to carry their calves to full term. It appears that the cause of these troubles is referable to a diseased condition of the mucous membrane of the vulva, vagina or uterus or to diseased ovaries. The treatment of the ovaries consists in manipulating them after a manual exploration through the rectum and vagina, with the object in view of rupturing cysts which vary in size from very small to the size of a hen's egg and of expressing from the ovary persistent corpora lutea (yellow bodies) which should disappear normally. The treatment of a diseased mucous membrane of the uterus requires the use of special instruments. The lips of the os are seized on either side by long forceps and the uterus is drawn back until the os is easily seen from the vulva. An entrance is then carefully made with dilator forceps followed by a special tube so constructed as to permit of the introduction of an antiseptic fluid and its return *without its contact with the vaginal mucous membrane. It appears that the mucous membrane of the uterus is capable of withstanding a much stronger antiseptic solution than is that of the vagina.* The presence of even a very minute quantity of pus or the existence of a very mild inflammation may prevent conception and this treatment helps to overcome such conditions. Both ovarian manipulations and uterine irrigations need to be repeated in most cases. It is needless to say that this phase of the treatment requires the services of a carefully trained and experienced man; but its application is attended by a goodly percentage of favorable results and its value to the pure bred cattle industry is far beyond the apparently high cost of application.

All cattle. In the aborting herd vaginal irrigations should be given to all non-pregnant females two or three times a week and the tail, and the buttocks and thighs of all the cattle should be frequently cleaned with a disinfectant. Only a slight amount of discharge may collect on these parts but due to its salty taste cattle will frequently lick the soiled parts of other cattle and it is claimed by the English investigators that cattle may acquire this disease through the alimentary canal. At the time of breeding the inferior abdominal surface of the bull should be disinfected and the sheath irrigated before and after service. In lieu of antiseptics for uterine and vaginal injections we are using sour whey obtained by curdling skim milk with the ordinary lactic acid organism or with *Bact. bulgaricum* and find this to be a very effective remedy.

Antiseptics suggested. For uterine and vaginal injections and for flushing the sheath of the bull before and after service, a non-toxic, non-irritating antiseptic should be used. For example, 1 to 1000 solution of potassium permanganate, ¾ per cent. solution of compound solution of cresol or ½ of 1 per cent. compound solution of iodine. Chinosol has been strongly recommended as a powerful non-irritating antiseptic but it is expensive.

Potassium permanganate. A solution of potassium permanganate approximately 1 to 1000 may be conveniently made as follows: Place 2 to 4 ounces of potassium permanganate in a quart fruit jar and then fill with water. Shake vigorously and allow all the undissolved crystals to settle to the bottom. The solution above the undissolved crystals is a saturated solution. To dilute for using, take 4 teaspoonfuls of the saturated solution to a quart of water or 2 ounces to one gallon of water. The supply of saturated solution may be kept up by adding water and sufficient potassium permanganate to keep more in the jar than will be dissolved. Always let settle before using.

Cresol. The cresols are very reliable but objectional in a dairy barn on account of their disagreeable odor. A ¾ per cent. solution of compound solution of cresol can be approximated by adding 2 teaspooonfuls of the compound solution of cresol to one quart of water, or 8 teaspoonfuls to one gallon of water. Clean water that has been boiled and cooled should always be used in making up solutions.

Sour whey. The use of sour whey for uterine and vaginal injections has already been referred to. We have been using sour whey for about three years and have obtained better results from its use than from the use of other antiseptics. The method of preparing this whey is as follows: Place fresh skimmed milk in a clean vessel and add a culture of the lactic acid organisms (cultures may be obtained from this laboratory at 25 cents each or creamery starter may be used if one is conveniently located relative to a creamery). Set in a warm place (70-80° F.) until a firm curd has formed. Break this curd up into a number of small pieces with a clean rod or spoon and filter through clean cheese cloth into clean fruit jars. This whey is to be injected in about 4 to 8 ounce doses daily into the uterus as long as it can be entered by ordinary methods and 2 to 4 ounce doses into the vagina until discharges have ceased.

Fresh whey should be made up at least once a week and kept in a cool place until used. If too much acidity has developed it may be diluted by adding water that has been boiled and cooled. Whether this is needed may be determined by tasting. If irritating to the mouth it should be diluted.

In warm weather it is sometimes difficult to keep sour whey prepared in this way longer than two or three days. Under such conditions the following method of preparation is suggested: Bring fresh skimmed milk to about 85° F. Add one dram of rennet in an ounce of clean water to a gallon of this milk, stirring constantly while adding. Let stand until a firm curd has formed. This will require 10 to 30 minutes. Break the curd up into several pieces, heat to the boiling point and filter through cheese cloth. Place the whey in sterile fruit jars and sterilize by setting the jars in a boiler of water and boil for about 30 minutes to one hour each day for three consecutive days. When boiling for the first time the tops and rubbers should be placed loosely on the jars but as soon as the boiling process ceases the top should be immediately tightened. At subsequent boilings the tops should be left undisturbed. It is suggested that some old towels or a wooden rack be placed in the bottom of the boiler to prevent the jars coming in contact with the bottom of the boiler. Whey put up in this way can be kept almost indefinitely. When desired for use, take that quantity of whey needed for two days' treatment and add a culture of the lactic acid organism and set in a warm place. In one to two days, enough acidity should have developed for use. Occasionally the lactic acid organisms fail to grow in whey, therefore it should always be tasted before using. A sour taste indicates that the organisms have been active.

Method of injections. After abortion the injection should be made into the uterus. The best way for the inexperienced man to accomplish this is to secure a piece of rubber tubing about 4 or 5 feet long and ½ inch in diameter or a fiber male (horse) catheter. Attach one end of either tube to a tin or glass funnel and into the other insert a metal (aluminum) tube about 14 to 16 inches long. If the rubber tubing is rather stiff (or if the catheter is used) it will not be necessary to use the metal tube. Introduce the hand into the vagina a distance of about 8 to 10 inches and locate the mouth of the uterus. Then introduce the metal tube through the mouth into the uterus. An attendant now pours the solution into the funnel, raises it and allows it to gravitate into the uterus. This treatment should be given every day as long as the mouth of the uterus is sufficiently open for the tube to be introduced without difficulty, then vaginal injections should be given two or three times a week until the uterine and vaginal discharges have ceased. During the treatment, the external genitals, buttocks and tail of the animal should be kept clean by washing with some disinfectant.

Treating the genital organs of the cow after abortion is a matter of very great importance. Drastic or improper treatment is more injurious than no treatment at all. Many cows have been made sterile and others have been killed by drastic treatment.

In the first place the hand should not be forcibly introduced through the mouth into the uterus. For a time after delivery the mouth of the uterus is sufficiently open to admit the hand without difficulty. It gradually closes, the time required depending upon the course of the diseased process in the uterus, until the hand cannot be introduced without force. Before introducing the hand the finger nails should be cut short and cleaned, the hand should be scrubbed with water and soap and then washed in a 1 to 50 solution of compound solution of cresol or 1 to 1000 solution of bichlorid of mercury.

Importance of selecting proper antiseptic. The selection of a solution for irrigation of the genital passages and the quantity to be used is not a matter of indifference. Let it be emphasized that a disinfection of the mucous membranes of the genital passages by strong disinfectants cannot be accomplished without producing serious injury to these membranes, especially to that of the vagina. No medicinal agent that can be safely used on the vaginal mucous membrane is likely to have any appreciable direct effect upon the bacterial life in the deeper layers of the membranes. The best that can be hoped for is a cleaning of the mucous membranes and a removal of the products of the diseased process and that of the bacterial growth that is going on. A flushing out process is desired and the solution used must be non-toxic and non-irritating or injury will be done. If the animal has cleaned well the safest solution that can be used is physiological salt solution made by adding 1 ounce of table salt to 1 gallon of clean water that has been boiled and cooled. The solutions of potassium permanganate, iodine and cresol already referred to may be used. The solution used should be warmed to about body heat before injecting. For the first injections after abortion, as much as 10 quarts of solution may be introduced if the uterine contractions are sufficiently strong to force the solution out, otherwise care should be taken not to introduce too large a quantity. Thereafter 1 to 3 pints may be safely used. Where a large quantity is used it should be siphoned off after it has remained in contact with the mucous membrane for a few minutes. This is a difficult procedure but sometimes can be accomplished by holding the hand in the mouth of the uterus and keeping the end of the rubber tubing used in introducing the solution near the floor of the uterus. The attendant now fills the funnel, grasps the rubber tubing just below the funnel between the thumb and forefinger and lowers it at the same time. When the funnel is lowered to a point below the end of the tubing in the uterus and the pressure is released, the solution in the uterus will be siphoned out. The mouth of the uterus must be held open during this process in order that air may be introduced. Sometimes the solution will cease to flow from the uterus. This may be due to the end of the tubing being pulled out of the solution in the uterus or it may be due to plugging the end of the tubing with fragments of the afterbirth or with a fold of mucous membrane of the uterus.

In making uterine injections a policy of gentleness and scrupulous cleanliness must be adopted and every effort made to avoid injury to the genital organs. In making vaginal injections it is not necessary to introduce the hand into the vagina, the tube is introduced into the vagina a distance of six to eight inches and one to two quarts of the solution are used for each injection.

It will be seen from the above that to properly treat the genital organs with antiseptics is a careful and troublesome process and one not entirely free from danger. As a safer and less troublesome, and equally effective, process we have adopted the use of sour whey. Sour whey is used with a high degree of success in human medicine in the treatment of gonorrheal infections and has met with success in our hands in the treatment of aborting animals. It is without injurious effects upon the genital mucous membranes and may be left in the uterine cavity. It does not seem to be necessary to use large quantities of it as is the case with the use of other antiseptics. Its good effects are probably due to the ability of the lactic acid organism and the products of its growth to prevent putrefaction and the growth of disease-producing organisms.

In the use of sour whey it is suggested that for the first day or two after abortion the uterine cavity may be irrigated with physiological salt solution before introducing the sour whey.

Breeding of affected cattle. No cow should be bred as long as there is any discharge from the genitals. Usually several months should intervene between abortion and subsequent breeding. The cow to be bred should have the external genitals and adjacent parts cleansed with a disinfectant. The inferior abdominal surface and the sheath of the bull should also be cleansed both before and after service. A 1 to 50 solution of compound solution of cresol or 1 to 1000 solution of bichloride of mercury may be used for cleansing the external parts of the cow and bull. This can be applied more effectively by scrubbing with a brush.

Treatment of bull. For irrigating the sheath of the bull a ¾ of 1 per cent solution of compound solution of cresol may be used. The method of irrigating the sheath of the bull is as follows: Use the same equipment as used in making uterine injections. Insert the tube into the sheath a distance of 3 to 4 inches. Grasp the sheath with one hand and hold tightly around tube so as to prevent leakage; have attendant pour solution into funnel and let gravitate into sheath. Still holding the sheath, massage carefully with the other hand so as to force the solution into all the folds and hold this solution in the sheath 2 to 3 minutes. Repeat once or twice.

CONCLUSION.

Infected milk. We have much faith in the above plan where persistently carried out. There is yet one possible difficulty, if not more, in the way of eliminating this disease. We cannot speak from experience on this point but we are now conducting an experiment which we hope will throw light on it. We refer to the possibility of calves becoming infected through milk from infected animals. Some work has been done on the presence of the abortus bacillus in milk with interesting results. Cows are known to have excreted this organism in their milk for a period of two to four years. This being true and if calves are susceptible to infection by the abortus bacillus while on a milk diet, another serious problem presents itself for solution. Mr. L. H. Cooledge of this laboratory has isolated directly from milk of aborting cows organisms corresponding to *Bact. abortus.* He has also shown that the milk serum of some aborting cows is capable of producing the agglutination and complement fixation reactions in the same manner as does the blood serum of these cows.

However, it is possible that there is no cause for alarm on account of this circumstance. It may be possible that this will prove to be a valuable prophylactic feature. In other words the consumption of quantities of milk containing the abortus bacillus day after day by the calf may result in the production of an active immunity. While our own experimental work with the use of living cultures of the abortus bacillus in the production of immunity is not encouraging, their use is reported on favorably by some. Further researches are necessary to reveal the truth. On the other hand, Prof. Williams urges the use of *heated* milk for raising calves in order to prevent their suffering from the bad effects of the presence of the germ.

Effect on man. What effect the consumption of such milk in the raw state may have on the human family, especially children, is not known. The work of Larsen and Sedgwick of Minnesota, and of Cooledge of this station indicates that children or adults may be affected, though not necessarily detrimentally, by the consumption of raw milk containing the abortus bacillus. The former report 425 complement fixation tests of the blood of children, 17 per cent of which were positive. It is claimed that the proportion of reactions would have been greater had the tests been confined to children fed with raw cow's milk.

CUCUMBER GROWING.

Circular No. 30.

Preparation of the Soil. To produce cucumbers profitably a location is necessary near a good sized town or a salting station and where enough help to do the picking can be secured. The crop will do well on a variety of soils. If planted on soil that is inclined to be light and also deficient in humus, the yield may be small unless rain is plentiful during July, August and September. If planted on heavy clay, the plants may suffer in a wet year from the soil becoming hard and packed, caused by tramping while picking the cucumbers. A clay loam that is well supplied with humus or decayed vegetable matter is very satisfactory. If it is tile drained, so much the better, for at picking time one must get on the ground to pick no matter how wet the soil may be.

A clover sod plowed early, worked down and harrowed occasionally until planting time makes a good seed bed. Timothy sod handled in the same way is also suitable if it is not too badly infested with cut worms. In fact, any soil intended for cucumbers should be plowed early and kept well worked until planting time. Such a method of handling pays for several reasons:

First.—It helps rid the soil of weeds. When soil is plowed, rolled and worked down reasonably fine, millions of weeds will germinate in a few days which can be destroyed by harrowing on a bright day. A second harrowing a week later will destroy a second lot of seedlings. A third and fourth harrowing will destroy a third and fourth lot of seedlings and the fourth lot will just about rid the top soil of weed seeds. The *cheapest, quickest and best way* to cultivate a crop is to harrow the soil before the seed for that crop is planted.

Second.—Keeping the soil well worked conserves moisture and enables the seed to germinate no matter how dry the weather may be at planting time. Soil that has not been plowed or worked until it is needed for planting is quite likely to be dry and full of clods. By the time these clods have been worked down sufficiently fine, the top soil has lost much of its moisture. Such soil might do as a seed bed for corn or for any crop with large seeds which may be planted quite deeply, but it will not be satisfactory for cucumber seeds which should not be planted over an inch deep. Soil which has been plowed early and harrowed occasionally will be moist an inch below the surface, even during a very dry time. Seed planted in such a soil will germinate readily and produce an even stand of vines which is worth a good deal to any grower.

Third.—Early plowing and frequent harrowing will put the soil in such a physical condition that it will not pack and bake after every rain. It will become loose, mellow and friable; rain falling upon it will drain away, leaving it in practically the same condition as it was before the rain, while a rain upon freshly plowed ground is quite likely to cause a crust to form. If seed has just been planted or if the young plants are just up, such a crust will be very injurious.

Fourth.—Early plowing and frequent harrowing makes the plant food in the soil available and plant food must be in solution before plants are able to use it. The more finely divided a substance is, the more readily will it dissolve. This clearly illustrates why a well prepared seed bed has advantages over lumps and clods. Harrowing the soil aerates it, that is, it enables the air to enter the soil more readily. Besides, soil contains minute forms of plant life, known as bacteria, which only thrive and multiply in the presence of air. These bacteria are beneficial inasmuch as they break down complex forms of plant food and make it more quickly available for the plants' use.

FERTILIZERS. Cucumbers are not hard on the soil but to be a successful crop the soil should be quite rich. They are quick growing plants and have not the time to rustle for a living, nor can the grower afford to have them do so. The thing to do is to provide them with an abundance of plant food so that they may grow, as it were, at high pressure. On the average land, they should not follow sugar beets, cabbages, potatoes or oats unless such land has, in the meantime, received a liberal application of barnyard manure or commercial fertilizer.

No fertilizer material gives better results than well rotted stable manure. If it is plentiful it may profitably be spread broadcast and plowed under, but if the supply is limited, it will be most economical if applied in the hills.

If commercial fertilizers are to be used, the ground should be plowed early and the fertilizer drilled broadcast as early in the season as possible. When the cucumbers are to be grown for pickles, a fertilizer of the following composition is recommended:

Nitrogen	3 to 4%
Available Phosphoric acid.	8%
Potash	6 to 10%

About one-half of the nitrogen should be in the form of nitrate of soda and the remainder as readily available organic nitrogen, such as dried blood or high grade animal tankage. A fertilizer of about this formula can be readily obtained of any manufacturer. From 500 to 1000 pounds, depending upon soil conditions, should be used per acre.

In using commercial fertilizers, it should be remembered that the best results will be obtained when they are used upon soils that are in good physical condition and well supplied with organic matter.

"Some growers of cucumbers advise the use of a certain amount of fertilizer in the drill a short time before the seed is planted but this has not been found the best method and is only justifiable when the amount of fertilizer available is very limited. If the soil is made exceedingly rich immediately around the plant and at a greater distance left without sufficient plant food, a rank vigorous plant is started, which the soil at a greater distance is not able to support. It is from the soil several feet away that the vine gets the greater part of its nourishment during the bearing season. For this reason, we advise the broad-casting of all fertilizers. After the soil has been thoroughly fertilized, it is not objectionable to use a small quantity of chicken or hog manure in the drill as a "starter," but when this is done, the manure should be thoroughly worked in the soil before the seed is planted. In all cases *care* should be taken to see that the seed is not brought into direct contact with the fresh manure. Nitrate of soda can also be used profitably as a "starter," and when used should be applied after the plant is up, care being taken to see that it does not come in direct contact with the stem or leaves. The best method of applying this is to open a shallow furrow, about three inches away from the plants. Spread the nitrate of soda in this furrow and cover with loose earth."

VARIETIES. Boston Pickling, Chicago Pickling and Snow's Perfection are the three varieties that are usually grown for pickles. They are prolific yielders, producing their cucumbers in clusters.

When cucumbers are grown to be sold direct to the consumer or to a retail grocer, some strain of the White Spine is generally grown. This is a prolific variety which yields fine straight cucumbers but which are a little too large in diameter to be suitable for bottling. This is also a good variety to grow when it is desired to produce early "slicers." Slicers are the large cucumbers suitable for slicing and are eaten fresh.

Some of the Long Green strains will produce "slicers" of better quality but not so early in the season as the White Spine. They are freer from seeds and the flesh is firmer and when well grown they will compare favorably with hot house cucumbers. Varieties suitable for hot house culture are not adapted to field conditions.

PLANTING TIME. "The best time for the planting of the seed is determined to a large extent by the nature of the soil and the latitude in which the cucumber is to be grown. On light warm soils seed can be planted earlier with safety than on the heavier soils. In all cases, however, the seed should not be planted until after the danger of frost is past and the soil is sufficiently warm to produce a quick, healthy germination of the seed. In Michigan, it has been found safest to plant from May 25th to June 10th, depending upon weather and soil conditions. If planted too early, or in cold soil, there is not only danger that one will get a slow, weak germination of the seed and a stunted weak plant but the plants are more frequently troubled by cut worms, wire worms and the striped cucumber beetles in May than they are in the warmer period in June."

PLANTING SEED. "Make a shallow furrow in the soil about three inches deep, allowing a space of seven feet between the rows. These furrows may be made by using a small shovel plow or any other convenient implement, such as a corn marker. Drop the seed immediately after the furrow is opened, planting one about every four inches; cover at once with mellow loose earth to a depth of about one inch. A hoe or rake may be used to push the earth over the seed—some find it convenient to use a hand or onion seeder. If the seed is planted in this way, the surface of the field should be immediately gone over with a drag, as it has been found that birds soon detect the marks of the seeder and in many cases, have followed them up and pulled out the seed before it has time to germinate. By using the drag the marks of the seeder are destroyed. In no case should the seed be planted until the surface of the soil is thoroughly pulverized and leveled. This will give a more even depth of the seed in the soil and a more uniform stand of plants."

CULTIVATION. "Begin cultivation just as soon as the plant makes its appearance above the surface of the soil. Use a hoe or garden rake to break the crust immediately around the plant and to keep the rows free from weeds. Cultivate at least once each week until the vines cover the space between the rows. The first cultivation may be to a depth of from three to four inches, but after the first week, the soil should not be cultivated to a depth exceeding one and one-half to two inches. Cultivate often enough to keep a dust mulch on the top of the soil and in all cases, cultivate as soon after a rain as the ground is dry enough to work. Bear in mind that frequent cultivation is essential to the conservation of the moisture, which all growing plants must have."

THINNING. "Too much attention cannot be given to the importance of thinning plants so that when they reach their maturity the vines will not be crowded or matted. If too many plants are left standing, they will be weak and lack the vitality necessary to produce a large yield or a good quality of pickles. One strong, vigorous plant can produce more pickles and better pickles than three or four weak plants. A straight, well formed pickle can only be grown on a strong healthy plant. It is impossible to pick a field of rank, matted vines as well or as quickly as one on which the vines are thinner. Where possible, two thinnings should be made. The first when the plants have reached a height of from four to five inches and just after the third leaf has unfolded. The thinning should be done with a hoe or knife and the weaker plants cut out, leaving one healthy plant standing about every twelve inches in the row. The second thinning should be made in the same way just after the plants fall over and begin to run and before the runners have reached a length not exceeding twelve inches, leaving one plant every twenty-four inches in a row. On muck soils, which are excessively rich in nitrogen, only one healthy stalk should be left every three feet in the row."

PICKING. Usually cucumbers are planted about June 1st, and picking will begin the latter part of July or the first of August, depending upon the thriftiness of the vines. The first two or three pickings will hardly pay for the gathering but it is very necessary to remove them for the good of the vines. The fewer the cucumbers that are allowed to become full grown, the better will the vines bear. Very few growers realize what a bad effect it has upon vines to allow the cucumbers to become overgrown or the injury that may be done in careless picking, which results in tearing and breaking the vines. In average growing weather, 48 hours may intervene between pickings and later in the season, 72 hours may not be too long. This is assuming that the vines are picked reasonably clean at each picking. It is impossible to find and remove every cucumber at any one time but that should be the aim. Large cucumbers in which seeds are forming reduce the vitality of the vines and a plant that has produced seeds becomes inactive and soon ceases to grow; but just as long as it is prevented from producing seed, it will endeavor to do so. The result is that small cucumbers in abundance will continue to form until the vines are killed by frost.

YIELD. There are so many factors which influence the yield that it is unwise to try to tell any prospective grower what he will get in bushels per acre. This much is certain, however; one acre of vines that is kept well picked will produce more bushels and, therefore, a much greater net profit than will two acres of equally good vines which are only indifferently picked. Two hundred bushels of marketable cucumbers is the average yield of one Michigan grower over a period of nearly twenty years. This was on a large acreage, so any fairly intelligent grower who does not plant too extensively should be able to secure such yields.

INSECTS. There are three or four insects which feed on the cucumber vine or its fruit. The striped cucumber beetle (Diabrotica vittata) attacks muskmelons and early planted cucumbers but does not work extensively in the main or late crop plantings. Most growers plant four or five times as many seeds as they desire plants, which allows the beetles to take some without ruining the stand. If the beetles work too badly, the vines may be dusted, preferably while the dew is on, with nine parts air slacked, or better, hydrated lime and one part arsenate of lead powder. Paris green should not be used as it may burn the vines. Coating the plants with a spray of six pounds arsenate of lead paste to fifty gallons of water makes them distasteful to the insects.

There is a plant louse which attacks cucumber vines. It is a sucking insect, so cannot be destroyed by applying a stomach poison, but must be killed by a contact spray if killed at all. If the first few hills affected are buried, vines and all, it will do much to control the pest. Keeping the vines thrifty is also a decided help since the louse always prefers to feed on sickly and stunted hills. Eight pounds of whale oil soap to fifty gallons of water makes a good spray but usually the enemies of the louse will hold it in check.*

DISEASES. Downy Mildew is a fungous disease causing a yellowing and shriveling of the leaves, starting with the older growth and rapidly extending to the tip of the plant. It is occasionally very severe in hot, moist weather but is controlled by spraying with Bordeaux mixture containing 6 pounds of lime, 3 pounds of copper sulfate and 50 gallons of water.

Anthracnose occurs principally on the leaves, where it produces circular brown spots from ¼ to ½ inch in diameter. These spots may tear out and leave ragged holes as the leaf matures. Spray as for Downy Mildew.

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*There is good reason to believe that the striped beetle and the louse are both concerned with the spreading of disease among cucumbers and related vines. The protection of the plants from these enemies seems therefore to be more imperative than was formerly supposed. It is therefore urged that all remnants of vines be destroyed as soon as possible after the crop is harvested, and that all rubbish in the vicinity of the patch be raked up and burned after cold weather sets in, with a view to killing some of the beetles at least, in their hibernating quarters.

For the plant-lice, nicotine proves very efficient, and is often easier to obtain than the whale-oil soap. Use one part of the 40% nicotine sulphate with 800 times its bulk of soap suds. It will often pay to turn the vines over so as to spray the under sides of the leaves, replacing them afterward.

Cucumber Scab (Spot Rot) is also a fungous disease and appears on the fruit in velvety olive green patches, often accompanied by a gummy exudate. Diseased fruits decay rapidly after picking and are worthless. The disease is worst in hot, moist weather where the vines are crowded. Destroy all trash and practice rotation. Spraying is of doubtful benefit.

Wilt is a sudden wilting of the vine without discoloration of the leaves due to a bacterium which enters and clogs the water vessels of the plant. Remove all diseased plants and keep down the striped beetle which spreads the disease.

Cucumber Mosaic (White Pickle) causes a stunting of the vine accompanied by a green and yellow mottling of the leaves. Pickles from diseased vines are warty and mottled green in color. It is spread by insects, especially plant lice, and probably by the pickers handling diseased and healthy plants. Remove all diseased vines at once and destroy the lice as fast as they appear.

C. P. HALLIGAN,
Acting Horticulturist.

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ANALYSES OF SOME MATERIALS SOLD AS INSECTICIDES AND FUNGICIDES.

Special Bulletin No. 74.

A. J. PATTEN AND D. C. KELLOGG.

The inspection and analyses of spraying materials reported herein are made under authority of an act of the Legislature of 1913 (Act 254, Public Acts of 1913). The full text of the law has been printed and copies may be obtained by addressing the Secretary of the State Board of Agriculture. Sections 1, 5, 6, and 7, which contain the more salient points of the law are here printed in full:

SECTION 1. It shall be unlawful for any person to manufacture, sell, offer or expose for sale within the State of Michigan any insecticide, Paris green, lead arsenate, or fungicide which is adulterated or misbranded within the meaning of this act; and any person who shall violate any of the provisions of this act shall be guilty of a misdemeanor and upon conviction thereof shall be fined not to exceed two hundred dollars for the first offense, and upon conviction for each subsequent offense shall be fined not to exceed three hundred dollars, or sentenced to imprisonment in the county jail for a period not exceeding ninety days, or both in the discretion of the court.

SEC. 5. The term "insecticide" as used in this act shall include any substance or mixture of substances intended to be used for preventing, destroying, repelling or mitigating any insects which may infest vegetation, man or animals, or households, or be present in any environment whatsoever. The term "Paris green" as used in this act shall include the product sold in commerce as Paris green and chemically known as the aceto-arsenite of copper. The term "lead arsenate" as used in this act shall include the product or products sold in commerce as lead arsenate and consisting chemically of products derived from arsenic acid (H_3AsO_4) by replacing one or more hydrogen atoms by lead. The term "fungicide" as used in this act shall include any substance or mixture of substances intended to be used for preventing, destroying, repelling, or mitigating any and all fungi that may infest vegetation or be present in any environment whatsoever.

SEC. 6. For the purpose of this act an article shall be deemed to be adulterated, in case of Paris green;

First, If it does not contain at least fifty percentum of arsenious oxide;

Second, If it contains arsenic in water-soluble forms equivalent to more than three and one-half percentum of arsenious oxide;

Third, If any substance has been mixed and packed with it so to reduce or lower or injuriously affect its quality or strength.

In the case of lead arsenate:

First, If it contains more than fifty percentum of water;

Second, If it contains total arsenic equivalent to less than twelve and one-half percentum arsenic oxide (As_2O_5);

Third, If it contains arsenic in water-soluble forms equivalent to more than seventy-five one hundredths percentum of arsenic oxide (As_2O_5);

Fourth, If any substances have been mixed and packed with it so as to reduce, lower, or injuriously affect its quality or strength: Provided, however, That extra water may be added to lead arsenate (as described in this paragraph) if the resulting mixture is labeled lead arsenate and water, the percentage of extra water being plainly and correctly stated on the label.

In the case of insecticides or fungicides, other than Paris green and lead arsenate:

First, If its strength or purity falls below the professed standard or quality under which it is sold;

Second, If any substance has been substituted wholly or in part for the article;

Third, If any valuable constituent of the article has been wholly or in part abstracted;

Fourth, If it is intended for use on vegetation and shall contain any substance or substances which, although preventing, destroying, repelling, or mitigating insects, shall be injurious to such vegetation when used as recommended by the manufacturer.

Sec. 7. The term "misbranded" as used herein shall apply to all insecticides, Paris green, lead arsenates, or fungicides or articles which enter into the composition of insecticides or fungicides, the package or label of which shall bear any statement, design, or device regarding such article or the ingredients or substances contained therein which shall be false or misleading in any particular, and to all insecticides, Paris green, lead arsenates, or fungicides which are falsely branded as to the state, territory, or country in which they are manufactured. For the purpose of this act an article shall be deemed to be misbranded, in the case of insecticides,

Paris greens, lead arsenates and fungicides:

First, If it be an imitation or offered for sale under the name of another article;

Second, If it is labeled or branded so as to deceive or mislead the purchaser, or if the contents of the packages as originally put up shall be removed in whole or in part and other contents shall have been placed in such packages;

Third, If in package form, and the contents are stated in terms of weight and measure, they are not plainly and correctly stated on the outside of the package; in this connection it is held to be permissible to state the average net weight of the package.

In the case of insecticides (other than Paris green and lead arsenates) and fungicides:

First, If it contains arsenic in any of its combinations or in the elemental form and the total amount of arsenic present (expressed as percentum of metallic arsenic) is not stated on the label;

Second, If it contains arsenic in any of its combinations or in the elemental form and the amount of arsenic in water-soluble forms (expressed as percentum of metallic arsenic) is not stated on the label;

Third, If it does not state plainly upon the label the correct names and percentage amounts of each and every ingredient of the insecticide or fungicide having insecticidal or fungicidal properties and the total percentage of inert ingredients present.

COLLECTION OF SAMPLES.

Some of the samples analyzed were collected during the spring of 1914 and the remainder were collected during the spring of 1915.

No attempt has been made to secure samples of all insecticides and fungicides sold in the State as the funds allowed for this work are not sufficient to permit of a complete collection each year. In the future it is planned to center our attention on a different class of materials each year and especially upon new preparations. In this way it will be possible to cover the entire field every two or three years.

One hundred four samples of various materials have been examined and the analyses will be found in the following pages.

LIME-SULFUR SOLUTIONS.

The principal ingredient of lime-sulfur solution is calcium sulfide and it is possible for the compound to consist of one part of calcium to 2, 3, 4 or 5 parts of sulfur depending upon various factors. The usual proportion of calcium to sulfur in commercial lime-sulfur solutions is 1 to 4-5.

This combination is usually referred to as calcium poly-sulfide and, according to an investigation conducted by Dr. Shafer of the Entomological division of the Michigan Experiment Station, the insecticidal and fungicidal properties of the solution are due to this compound. Other compounds (calcium thiosulfate, calcium sulfite and calcium sulfate) are also formed in small quantities but, as they probably have little or no insecticidal or fungicidal value are not included in the table.

Samples 4818, 4821, 4822, 4825, 4826, 4827, 4833, 4837, were collected in the spring of 1914, the remainder being 1915 stock.

All of the samples analyzed were found to be above the standard guaranteed by the manufacturers.

Laboratory Number.	Manufacturer.	Baumé.		Total Sulfur.		Calcium Polysulfide.
		Found.	Guaranteed.	Found.	Guaranteed.	
				%	%	%
4818	A. B. Ansbacher, New York City	32.4	33	25.04	24	29.48
4819	Jas. A. Blanchard, St. Joseph, Mich	32.3	....	24.94	20	29.54
4820	Jas. A. Blanchard, St. Joseph, Mich	30.8	....	22.47	20	27.56
4822	Carpenter-Udell Chem. Co., Grand Rapids, Mich	31.8	....	24.23	23	28.88
4821	Carpenter-Udell Chem. Co., Grand Rapids, Mich	31.5	....	23.56	23	27.42
4823	Carpenter-Udell Chem. Co., Grand Rapids, Mich	32.0	....	24.39	23	29.31
4824	Carpenter-Udell Chem. Co., Grand Rapids, Mich	32.0	....	24.62	23	29.48
4825	Dow Chem. Co., Midland, Mich	33.8	33	26.51	25	31.63
4826	Dow Chem. Co., Midland, Mich	33.4	33	25.98	25	31.34
4827	Dow Chem. Co., Midland, Mich	33.9	33	26.18	25	31.25
4828	Dow Chem. Co., Midland, Mich	33.7	33	25.84	25	30.79
4829	Dow Chem. Co., Midland, Mich	33.4	33	25.79	25	30.81
4830	Dow Chem. Co., Midland, Mich	33.3	33	25.30	25	29.84
4831	Grasselli Chem. Co., Cleveland, Ohio	33.0	33	25.64	25	30.88
4832	Sanocide Spray Co., Fennville, Mich	32.5	32	25.17	25	29.63
4833	Sherwin-Williams Co., Chicago, Ill	32.5	....	24.61	....	29.14
4834	Sherwin-Williams Co., Chicago, Ill	30	....	23.02	....	27.33
4835	So. Haven Chem. Co., So. Haven, Mich	32.2	....	24.65	23	29.82
4836	So. Haven Chem. Co., So. Haven, Mich	33.0	32	25.16	24	30.23
4837	Toledo Rex Spray Co., Toledo, O	32.7	31	25.33	24	29.43
4838	Toledo Rex Spray Co., Toledo, O	32.5	31	25.38	24	30.24
4839	Toledo Rex Spray Co., Toledo, O	32.7	31	25.20	24	29.45
4840	Van The Tool Man, Lansing, Mich	31.0	....	23.80	23	28.76

SOLUBLE SULFUR COMPOUND.

Three samples of Soluble Sulfur Compound manufactured by the Niagara Sprayer Co. were analyzed. In making this material a compound of sodium is used instead of lime. It is granular and readily soluble in water but deteriorates rapidly if exposed to the air. The package containing it should be tightly closed at all times.

Lab. No.	Manufacturer.	Total Soluble Sulfur.	Insoluble Sulfur.	Sodium Polysulfide.
4841	Niagara Sprayer Co., Middleport, N. Y	55.85	2.42	40.52
4842	Niagara Sprayer Co., Middleport, N. Y	59.35	0.44	45.16
4843	Niagara Sprayer Co., Middleport, N. Y	60.40	....	....

LEAD ARSENATE.

The insecticide law fixes the standard for lead arsenate, making it compulsory for all samples to contain at least 12.50% arsenic oxide and not more than 0.75% arsenic oxide soluble in water nor more than 50% water.

The results of analysis show that all the samples comply with the requirements demanded by law, with one exception, in which case, the water-soluble arsenic oxide is slightly above the legal limit.

Twenty-five samples were analyzed, eight of which, were in the form of dry powder and seventeen as paste.

Samples 4853, 4858, 4844, 4850, 4861 and 4863 were collected during the spring of 1914 and the remainder during 1915.

Laboratory Nnmber.	Manufacturer.	Water.	Arsenic Oxide.				Lead Oxide.
			Total.		Water Soluble.		
			Found.	Guar-anteed.	Found.	Guar-anteed.	
	Dry Powder:	%	%	%	%	%	%
4863	Corona Chem. Co., Milwaukee, Wis	0.20	31.56	30.	0.14	0.75	65.05
4862	Corona Chem. Co., Milwaukee, Wis	0.23	32.18	30.	0.23	0.75	64.16
4861	Corona Chem. Co., Milwaukee, Wis	0.21	32.70	30.	0.21	0.75	64.16
4864	Corona Chem. Co., Milwaukee, Wis	0.23	34.29	30.	0.17	0.75	63.89
4865	Corona Chem. Co., Milwaukee, Wis	0.21	34.43	30.	0.15	0.75	64.00
4866	Grasselli Chem. Co., Cleveland, O	0.41	29.69	......	0.23	0.75	67.77
4867	Niagara Sprayer Co., Middleport, N. Y	0.36	29.34	......	0.26	......	66.03
4868	Sherwin-Williams Co., Chicago, Ill	0.36	33.55	......	0.08	......	63.78
	Paste:						
4844	A. B. Ansbacher, New York City	39.63	18.62	15.0	0.44	0.50	39.63
4845	A. B. Ansbacher, New York City	44.32	16.96	15.0	0.43	0.50	36.60
4846	A. B. Ansbacher, New York City	43.96	17.72	15.0	0.32	0.50	36.72
4847	A. B. Ansbacher, New York City	45.13	17.43	15.0	0.43	0.50	35.49
4848	Jas. A. Blanchard, St. Joseph, Mich	47.20	14.23	12.5	0.18	0.75	36.14
4849	Jas. A. Blanchard, St. Joseph, Mich	39.01	17.42	12.5	0.23	0.75	42.25
4850	Carpenter-Udell Chem. Co., Gd. Rapids, Mich	44.24	12.67	12.5	0.07	0.75	40.31
4851	Carpenter-Udell Chem. Co., Gd. Rapids, Mich	44.54	17.66	12.5	0.37	0.75	35.98
4852	DeVoe & Raynolds Co., New York City	48.08	16.10	12.5	0.15	0.75	34.43
4853	Dow Chem. Co., Midland, Mich	47.74	15.43	15.0	0.24	0.75	35.82
4854	Dow Chem. Co., Midland, Mich	49.99	17.03	15.0	0.20	0.75	32.56
4855	Grasselli Chem. Co., Cleveland, O	44.60	15.02	......	0.57	......	35.60
4856	Hemingway & Co., New York City	50.39	16.14	......	0.36	......	31.85
4857	Merrimac Chem. Co., Boston, Mass	41.73	16.38	......	0.86	......	39.70
4858	Sherwin-Williams Co., Chicago, Ill	44.21	15.43	......	0.17	......	40.70
4859	Toledo Rex Spray Co., Toledo, O	44.89	15.76	14.5	0.37	0.75	37.68
4860	Van The Tool Man, Lansing, Mich	28.84	17.00	......	......	......	51.72

PARIS GREEN.

The prescribed standard for the composition of Paris green is not less than 50% arsenious oxide nor more than 3.50% water-soluble arsenious oxide.

Fifteen samples have been analyzed all of which were collected since January 1st, 1915. In every case the amount of arsenious oxide found was well above the amount guaranteed, though, in five samples, (4871, 4873, 4875, 4877 and 4881) the amount of water-soluble arsenious oxide was more than the amount prescribed by law.

Laboratory Number.	Manufacturer.	Arsenious oxide.				Copper Oxide.
		Total.		Soluble.		
		Found.	Guaranteed.	Found.	Guaranteed.	
		%	%	%	%	%
4869	A. B. Ansbacher, New York City	57.10	50	2.11	3.50	29.53
4870	A. B. Ansbacher, New York City	56.51	50	1.49	3.50	29.72
4871	E. J. Barry, New York City	56.36	50	4.32	3.50	29.41
4872	Jas. A. Blanchard, St. Joseph, Mich	58.77	50	2.60	3.50	28.52
4873	Jas. A. Blanchard, St. Joseph, Mich	57.13	50	4.58	3.50	29.07
4874	Carpenter-Udell Chem. Co., Grand Rapids, Mich	56.66	50	3.28	3.50	30.42
4875	Carpenter-Udell Chem. Co., Grand Rapids, Mich	56.81	50	4.37	3.50	28.82
4876	Corona Chem. Co., Milwaukee, Wis	56.68	50	2.79	3.50	29.47
4877	Detroit White Lead Works, Detroit, Mich	55.32	50	3.96	3.50	29.55
4878	Devoe and Raynolds, New York City	57.04	56	2.91	3.00	30.12
4879	Morris Herrman & Co., New York City	56.54	55	1.80	3.50	29.46
4880	Fred L. Lavenburg, New York City	57.16	50	3.10	3.50	30 12
4881	Fred L. Lavenburg, New York City	59.06	50	3.75	3.50	30.16
4882	Sherwin-Williams Co., Chicago, Ill	56.66	50	1.59	3.50	30.40
4883	Sherwin-Williams Co., Chicago, Ill	55.82	50	3.10	3.50	29.09

BORDEAUX MIXTURE.

Nine samples of prepared Bordeaux mixture were collected and analyzed. Two of the samples were in the form of dry powder and seven were in paste form. Samples 4888, 4889, 4891 and 4892 were collected during the spring of 1914 and the others during 1915.

One sample (4892) contained only a trace of copper and was composed almost entirely of lime. No other sample of this brand was found on the market.

Laboratory Number.	Manufacturer.	Water.	Copper.	
			Found.	Guaranteed.
		%	%	%
4884	Jas. A. Blanchard, St. Joseph, Mich	74.11	4.86	*4.56
4885	Carpenter-Udell Chem. Co., Grand Rapids, Mich	76.80	6.55	6.00
4886	Grasselli Chem. Co., Cleveland, O	55.47	9.52	4.50
4887	Hammond's Slug Shot Wks., Beacon, N. J	58.79	6.14	5.50
4888	Sherwin-Williams Co., Chicago, Ill	53.92	7.72	6.50
4889	Sherwin-Williams Co., Chicago, Ill	61.24	5.20	6.50
4890	Sherwin Williams Co., Chicago, Ill	52.02	8.23	6.50
4891	Sherwin-Williams Co., Chicago, Ill		11.60	11.00
4892	Target Brand Co., Martinsburg, W. Va	1.12	0.25	16.00

*Calculated from 7% copper hydrate.

TOBACCO PRODUCTS.

Ten samples of tobacco products were collected and analyzed, all of which, contained nicotine in amounts equal to or exceeding that guaranteed by the manufacturers.

Laboratory Number.	Manufacturer.	Nicotine.	
		Found.	Guaranteed.
		%	%
	Jas. A. Blanchard, St. Joseph, Mich.		
4893	"Powdered Tobacco"	0.38	....
	Carpenter-Udell Chem. Co., Grand Rapids, Mich.		
4894	Nicotine solution	10.30	10
4895	Nicotine solution	9.97	10
	Detroit Nicotine Co., Detroit, Mich.		
4896	"To-Bak-ine" liquid	46.38	45
4897	"To-Bak-ine" liquid	45.66	45
	Kentucky Tobacco Products Co., Louisville, Ky.		
4898	"Black Leaf 40"	41.40	40
4900	"Nico Fume"	41.44	40
	Parke Davis Co., Detroit, Mich.		
4901	"Nicotine"	12.78	10
	F. A. Thompson & Co., Detroit, Mich.		
4902	"Rose Nicotine"	11.85	10
4903	"Rose Nicotine"	11.65	10

MISCELLANEOUS MATERIALS.

4904 Bordeaux Arsenate Paste. Manufactured by A. B. Ansbacher, New York City.

	Found.	Guaranteed.
	%	%
Water	51.27	....
Arsenic (Metallic)	7.42	5.50
Arsenic (Metallic, water soluble)	0.05	0.50
Lead Oxide	26.21	....
Copper Oxide	3.89	3.75

4905 }
4906 } Bug Death. Manufactured by Danforth Chem. Co., Leominster, Mass.
4907 }

	Lead Oxide.		Zinc Oxide.	
	Found.	Guaranteed.	Found.	Guaranteed.
	%	%	%	%
Sample No. 4905	5.09	5.0	67.79	47.0
Sample No. 4906	7.41	5.0	60.00	47.0
Sample No. 4907	4.92	5.0	60.86	47.0

4908 Cut Worm and Grub Destroyer. Manufactured by Carpenter-Udell Chem. Co., Grand Rapids, Mich.

	Found.	Guaranteed.
	%	%
Arsenic (metallic)	0.83	*0.95

*Calculated from 1.25% As_2O_3.

4909 Arsite }
4910 Calite } Manufactured by Morris Herrman & Co., New York City.

	Water.	Arsenic (metallic)		Arsenic (sol. in water)	
		Found.	Guaranteed.	Found.	Guaranteed.
		%	%	%	%
Sample No. 4909	....	31.05	28.8	31.05	28.8
Sample No. 4910	67.07	11.55	11.4	0.45	0.5

4911 Kerosene Emulsion. Manufactured by Jas. A. Blanchard Co., St. Joseph, Mich.

	Found.	Guaranteed.
	%	%
Kerosene	80.00	38-43

4912 Slug Shot. Manufactured by Hammond Slug Shot Wks., Fishkill, N. Y.

	Found.	Guaranteed.
	%	%
Sulfur	5.54	6.00
Copper Oxide	1.23	....
Arsenic (metallic)	0.76	....

4913 Thrip Juice. Manufactured by Hammond Slug Shot Wks., Fishkill, N. Y.

	Found.	Guaranteed.
	%	%
Nicotine	2.11	1.
Potash	8.04	7.80
Resin and soap	38.05	37.70

4914 London Purple. Manufactured by Hemingway's London Purple Co., New York City.

	Found.
	%
Arsenic Oxide	4.84
Arsenious Oxide	21.43

4915 Insectonos. Manufactured by Wm. Branson; contains Pyrethrum as active ingredient, inactive ingredients, charcoal and essential oils.

4916 Hellebore. Manufactured by Jas. A. Blanchard, St. Joseph, Mich. All tests indicate that sample is pure hellebore.

4917 }
4918 } Simplex Manufactured by H. J. Smith Co., Utica, N. Y.

	Sulfur.		Arsenic (metallic)		Lead Oxide.	
	Found.	Guaranteed.	Found.	Guaranteed.	Found.	Guaranteed.
	%	%	%	%	%	%
Sample No. 4917	16.30	20	2.73	....	8.90	....
Sample No. 4918	25.84	20	2.48	....	10.60	....

4919 Tuber Tonic, Dry
4920 Tuber Tonic, Paste } Manufactured by Sherwin-Williams Co., Chicago, Ill.

	Sample No. 4919		Sample No. 4920	
	Found.	Guaranteed.	Found.	Guaranteed.
	%	%	%	%
Water	....	....	54.36	....
Arsenic (metallic)	18.56	17.00	10.06	8.50
Arsenic, soluble (metallic)	1.49	6.00	0.71	2.00
Copper	13.46	14.00	7.18	6.30
Lead oxide	7.79	....	3.80	....

4921 Zenoleum Lice Killer. Manufactured by Zenner Disinfectant Co., Detroit, Mich.
Nicotine..........0.51 per cent.

4958 Treevax. Manufactured by Treevax Chemical Co., Hicksville, O.

	Found.
Sulfur	62 per cent.
Saltpeter	27 per cent.
Iron oxide	11 per cent.

DURABILITY OF CONCRETE DRAIN TILE.

Special Bulletin No. 75.

BY O. B. WINTER AND H. H. MUSSELMAN.

The extensive use of concrete in manufacturing drain tile is a somewhat modern development, yet there are in existence today concrete tile drains which were laid twenty-five or more years ago and which, so far as the concrete tile itself is concerned, have given eminent satisfaction. Within recent years the manufacture of concrete tile has developed into an industry of considerable magnitude. In fact the strides made during the past few years have been very rapid. But the tile produced by some manufacturers, varies greatly in quality, and the manufacturers as well as the users are ignorant as to the causes of both success and failure in making tile of good quality. This situation has led to a number of investigations, carefully conducted by research workers, in the effort to distinguish between good and poor tile and to discover the causes of success as well as of failure in the production of tile of good quality.

As numerous requests for information in regard to these points have come to the College Experiment Station, an investigation was undertaken to determine, if possible, the direct causes of disintegration of concrete tile in Michigan soils. The conclusions of this investigation are not final but the findings, so far reached, indicate that concrete tile can be depended upon when made according to certain processes which have been fairly well established as governing success.

Whenever the disintegration of tile has been noted in our experiments it has been found to be due to one or more of the following causes:

(1) the use of too lean a mixture,

(2) the use of too dry a mixture,

(3) improper hardening of the product after it is formed.

(4) placing the tile in the ground before the concrete has sufficiently hardened to afford proper resistance to the solvent action of soil water upon the cement. The first three of these causes contribute to the production of a porous tile wall structure.

Experiments conducted by the Bureau of Standards in an endeavor to determine the action of alkali and sea-water on cements indicate quite clearly that:

"Portland cement mortar or concrete, if porous, can be disintegrated by the mechanical forces exerted by the crystallization of almost any salt in its pores if a sufficient amount of it is permitted to accumulate; and the rapid formation of crystals is brought about by drying; and, as larger crystals are formed by slow crystalization, there would be obtained the same results on a larger scale, but in greater time, if slow drying were had. Porous stone, brick and other structural materials are disintegrated in the same manner. Therefore in alkali regions where a concentration of salts is possible a dense, nonporous surface is essential."

This conclusion is interesting even in its reference to the action of alkali, which, however, is not a problem to be contended with in Michigan soils.

Owing to the fact that our investigations were not begun until late in the fall of 1914, we have not been able to place tile in drains and report as to its durability. In this respect, our findings, as already mentioned, cannot be regarded as conclusive, since, to determine durability under actual service conditions requires experiments extending over a period of several years. One marked characteristic of properly made concrete tile is its resistance to the action of frost or alternate freezing and thawing soil conditions.

In our work we made experiments in manufacturing and hardening tile and then tested specimens which were porous by causing solutions to percolate through the walls, thus endeavoring to determine what changes took place in the solutions and in the tile. However, relatively few of the tile used for test purposes were made in our laboratory. Most of them were samples sent in from different parts of the State, which were not up to the average in displaying an observance of recognized requirements of manufacture. These samples were accompanied by reports giving information concerning the processes of manufacture, such as mixtures, type of machine used and method of hardening; and a description of conditions under which they were placed in the ditch. Some of them were apparently sound and in good condition but others gave evidence of having been poorly manufactured and, as a result, had undergone considerable disintegration.

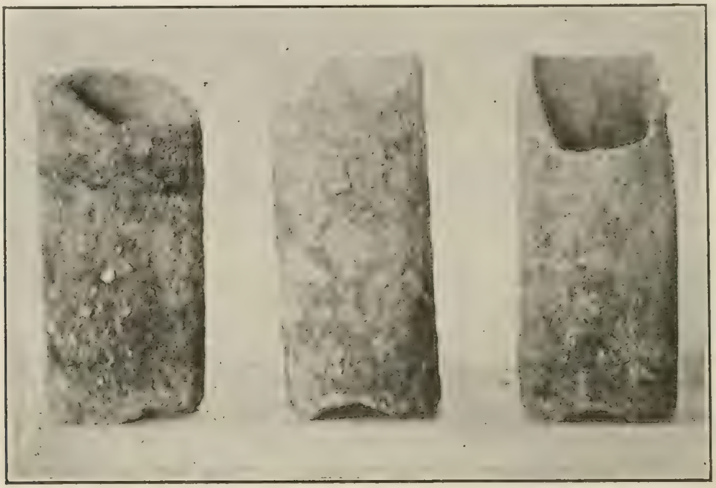


Fig. 1.—Disintegrated tile taken from a drain 18 months after being laid. Subsequent investigations proved that they were poorly made and placed in the ditch without being properly hardened. Under such conditions disintegration is almost sure to follow.

Chemical tests and analyses of the tile were made but gave no clue as to the cause of the disintegration. Our experiments included placing apparently sound tile so as to expose them to the action of the elements, to the action of water in a river bed—to determine what effect a large amount of water coming in contact with the surface would have—and to the action of sewage by placing them in the discharge waters at a sewer outlet.

Tile used in these experiments were left exposed to the conditions described for about four months, at the conclusion of which time none showed any evidence of having been affected by the several conditions of exposure described. Porous tile were placed in soil, and water caused to percolate through their walls. Here again no disintegration was noticeable; but analyses of the water which had passed through the tile structure showed that some of the cement had been dissolved. It should be mentioned here, however, that tile can be manufactured so that under the usual conditions in drains, water will not percolate through the wall

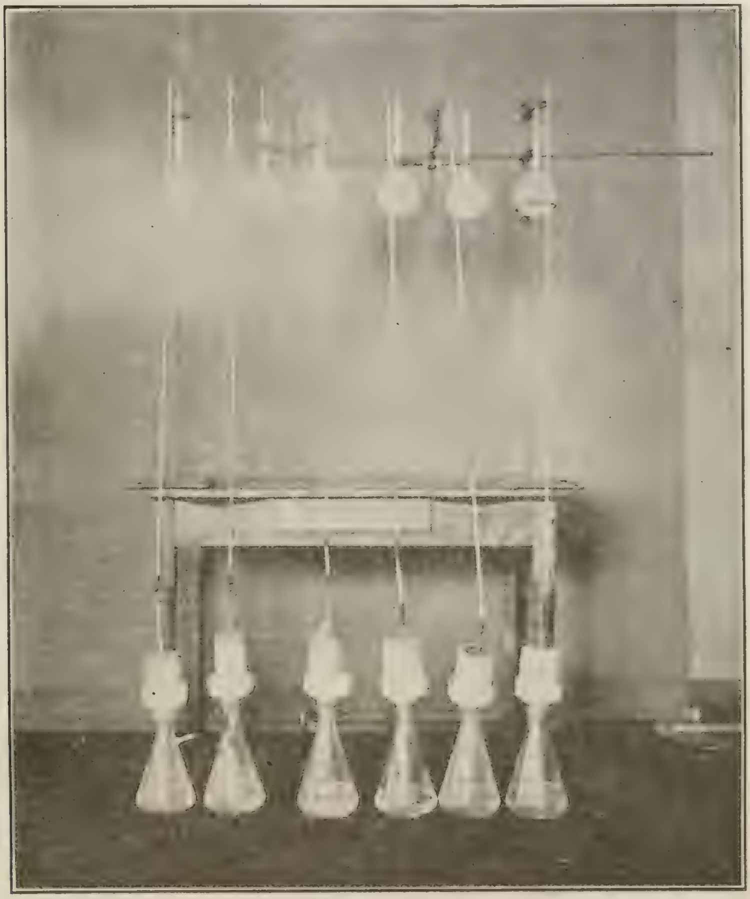


Fig. 2.—Apparatus used in determining the effect of various solutions on experimental concrete cups.

structure; in fact the process of manufacture should be such that the tile wall will be impervious in the usual service conditions.

To show the effect of soil water upon the cement in concrete tile, considerable laboratory work was done in preparing experimental porous cups from pure quartz sand and cement, then causing different solutions to pass through their structure. These experiments were so conducted that a considerable quantity of the solutions used was passed through the cups; and in all cases, including experiments in which pure water was used, a portion of the cement was dissolved and the cups showed disintegration in a degree sufficient to loosen a small amount of sand on the inside surface of each. The water caused to pass through the cup structure formed small channels through the concrete, that gradually became larger as percolation continued.

These experiments convince us that any solution percolating through concrete tile will dissolve some of the cement; in other words, some of the material which is necessary to maintain the tile structure intact, and points conclusively to the necessity for an impervious tile wall structure. Experiments also showed that solutions would percolate through incompletely hardened tile much more rapidly than through tile that had been properly and completely hardened; so the action of solutions upon partially hardened concrete tile is greater than upon those which have been properly hardened.

In a tile which has been well made of properly proportioned materials, and, after formation properly hardened, the wall structure will be so nearly impervious that it seems probable the small pores which may exist will be filled very quickly with fine material from the soil in which such tile is laid, and thus afford added protection against the possibility of soil waters dissolving the cement.

Our first experiment with concrete cups was directed toward making a cup that would be porous rather than impervious. The next experiments along similar lines were directed toward producing an experimental concrete cup of structure so dense that the concrete would resist the passage of solutions, even against a small amount of water pressure such as might exist, for instance, in a drain. Conclusions reached from these preliminary experiments, seem to point to the following as the most important factors for consideration in manufacturing concrete tile to fulfill desired requirements.

(1) A Portland cement, meeting the requirements of the standard specifications for Portland cement of the American Society for Testing Materials, as revised to date.

(2) Clean and preferably siliceous sand, graded in size from the finer particles to those which will just pass a ¼-inch mesh screen, for all tile ten inches and less in diameter.

(3) Proper and accurate proportioning of the cement and sand. The method of measuring materials should be one which will insure separate and uniform proportions of each of the materials at all times.

(4) Thorough mixing of materials, preferably by a power-operated batch mixer, and continuing for at least one minute after all materials, including water, are in the mixer.

(5) Using a machine that accomplishes thorough packing of materials at proper consistency.

(6) All other conditions of manufacture having been as outlined, hardening in a properly equipped and operated steam room will produce tile of the highest grade. When, however, hardening by water vapor is not possible, tile must be kept constantly wet on the surface by sprinkling with water for not less than seven days under favorable weather conditions, and longer during cold weather.

Cement: If the cement to be used in tile manufacture meets the requirements of the American Society for Testing Materials, the user need concern himself little as regards this material, other than to make certain that if stored for a considerable time, it is protected from dampness. If not so protected, moisture will be absorbed and result in some of the material becoming hard. In this condition it is worthless for tile manufacture.

Aggregate: Aggregate, consisting of sand, crushed stone or gravel screenings, preferably of siliceous nature, should be clean, well graded from fine to coarse and should pass, when dry, a screen having four square meshes per linear inch for all sizes up to ten inches; in sizes larger than ten inches it will be found practicable to use aggregate having a maximum size of one-half an inch. For ordinary work the maximum sized particles should not exceed, in greatest dimension, one-half the thickness of the tile wall. Cleanness is an essential. No matter how well materials may be mixed or graded, organic matter and clay coating on the particles will prevent the cement from adhering to and binding them together. In no case should sand or gravel containing more than three per cent, by weight, of clay, or other organic or soluble matter be used. Sharpness is not considered an essential quality.

Proportioning: Numerous experiments have conclusively proved that a good concrete cannot be made from improperly or indefinitely proportioned materials nor from materials which are not uniformly graded from the smallest to the largest sizes permissible, so as to reduce voids to a minimum. Natural-mixed aggregates, that is, bank-run material, should not be used as coming from the deposit, but should be screened over a $\frac{1}{4}$-inch mesh screen and remixed in definite proportions. In order to make tile as strong and dense as possible a maximum amount of the largest sized particles permissible should be used, then just a sufficient quantity of the smaller sizes to fill voids.

Deficiency of fine materials in the aggregate causes difficulty in the manufacturing process, loss of tile when removing the casing, rough surfaces, stone-pockets and pin-holes through which water spurts when internal water-pressure tests are applied. Deficiency of fine material within rather wide limits does not decrease the strength of the finished product.

Excess of fine material causes low strength in finished tile, and with ordinary mixture tends to produce tile which will show seepage under internal pressure tests. The tendency to use an excess of fine material is to be particularly guarded against, because, unless tile is tested, the manufacturer may be deceived as to the quality of the product which he is making, owing to the smooth and (to the uninitiated) workmanlike appearance of tile in which aggregate containing an excess of fine material has been used.

Some idea of the correct relative proportion of the different sized grains will be obtained by observing that the practice which has been recognized as best, specifies that not more than twenty per cent shall pass a sieve having fifty meshes per linear inch and not more than six per cent shall pass a sieve having one hundred meshes to the linear inch.

When aggregate is graded as specified, the concrete mixture for tile should consist of not less than one sack of Portland cement to three cubic feet of sand meeting the requirements already stated. Methods of measuring the materials should be such as to insure separate and uniform proportions of each ingredient at all times.

The Bureau of Standards has recently published, in its Technologic Papers No. 44, the results of a year's investigations on the durability of cement drain tile in alkali soils. In a summary of these investigations the Bureau states that the published results of the year's labors are by no means to be taken as conclusive but that, so far, its observations have pointed to the necessity for employing only the best materials and good workmanship in manufacturing drain tile and preferably adhering to mixtures no leaner than one sack of cement to three cubic feet of sand. In the Bureau experiments it was disclosed that drain tile properly manufactured of such mixtures is "apparently unaffected structurally when exposed for one year in operating drains in very concentrated alkali soils." This should point to an ultimate conclusion that the durability of concrete tile rests entirely upon the process of manufacture, which means an observance of requirements previously outlined.

A good method of examining finished concrete to determine whether the proportioning has been properly done is the following: Take several small broken pieces of the finished product, smooth some of the broken surfaces on a grindstone and examine these finished surfaces with a small lens or reading-glass. Many voids or air-spaces indicate too little fine material or poor packing, while too little coarse material will be indicated by a great deal of mortar between the larger particles. The proportion of cement used in concrete tile is greater than for other kinds of concrete work. This excess of cement is used to insure filling all the void spaces and coating all the sand particles with cement, the particles of which are ground very fine.

Mixing: Too much emphasis cannot be placed on the necessity for thoroughly mixing the materials. For this purpose a batch mixer is advisable because, if properly used, it may be expected to give the greatest uniformity of results, provided mixing be continued for at least one minute after all materials, including the water, are in the mixer. Enough water should be used to produce a consistency that will allow immediate removal of the outer casing from the tile, yet wet enough so that when the outer casings are removed web-like markings, or water-marks, will appear on the outside tile surface, indicating a sufficient amount of water. Interior surfaces of the tile should show trowel marks caused by moisture coming to the surface under the troweling action of the revolving packer head, or core, in case such is used. It is recommended that an automatic measuring device be used to measure the amount of water for each batch of concrete and, after the desired consistency has been determined, this amount should be used in each batch until working conditions demand a change.

Forming: The tile should be formed in such a manner as to insure a dense and uniformly compact product with smooth ends and inner surfaces. They should also be uniformly packed from top to bottom to prevent planes of weakness in the tile. The thickness of the tile walls should be as nearly uniform as possible to give uniform strength and to insure possibility of being laid in the ditch without irregularities in the grade.

Steam Hardening: No other step in the process of making concrete products is of greater importance than observing requirements necessary to uniform hardening of the finished product. This process is often spoken of as "curing" and best methods of tile manufacture include hardening in specially arranged steam chambers. In the preparation of these chambers, two requirements must be observed, as neglect of these sometimes causes improper hardening.

(1). The steam hardening chamber must be so tight as to prevent circulation of air and the consequent existence of a heated atmosphere not thoroughly saturated with water vapor which would result in evaporation of water from the tile walls.

(2) Steam should not be allowed to enter the hardening chamber under pressure in such a manner as to strike the green tile. The effect of this is to heat it quickly and cause the evaporation of water from the interior of the tile walls and destroy the product. Proper hardening is absolutely essential.

Within sixty minutes after removing the outer casings from the tile, they should be placed in the steam room in a temperature not lower than 50 degrees Fahrenheit. Twelve hours later the temperature in the steam room should be raised to between 100 and 130 degrees Fahrenheit and an atmosphere saturated with water vapor maintained by introducing steam from a steam boiler into the chamber. The steam should be introduced through a perforated pipe laid, with the perforations down, in a trough of water on the floor of the room.

Two conditions of outside temperature should be considered in the hardening process:

(a) When the outside temperature during the daytime does not fall below 50 degrees Fahrenheit the tile should be subjected to steam as described above for not fewer than 48 hours, after which they may be removed from the chamber and piled in the yard. They should then be sprinkled not fewer than three times daily for seven days. They may be shipped after having lain in the storage yard for fourteen days or more.

(b) When the temperature of the outside atmosphere falls below 50 degrees Fahrenheit during the daytime, tile should be subjected to steam as described for not less than 96 hours, after which they may be piled in the yard. They need not receive any further treatment but should remain in the storage yard for at least fourteen days.

Water Hardening: When it is found impracticable to introduce water vapor into the chamber, the tile should be handled in the same manner as described for steam hardening, until they have become sufficiently hard so that the application of water does not injure them. The tile should then be kept constantly wet on the surface by sprinkling with water for not less than seven days, for case (a) and fourteen days for case (b), and the temperature be maintained not lower than 70 degrees Fahrenheit in the hardening chamber. After removal from the chamber the tile should be treated as described above for steam hardening, except that the period of storage in the yard should be at least fourteen days.

Steam and Water Hardening: In cases where it is desired to use a combination of steam and water in hardening the tile, they should be hardened in the chamber under conditions described above for steam hardening, until such time as they are sufficiently hard to permit piling one on top of the other. They may then be removed to a sprinkling chamber where they will be at all times protected from drafts of air. Here they must be kept constantly wet on the surface by sprinkling for a period of at least two days for case (a), and for at least seven days for case (b). The temperature in the sprinkling chamber should be maintained not lower than 70 degrees Fahrenheit for the periods mentioned. After removal from the sprinkling chamber, the tile should be treated as described for steam hardening, except that the period of storage in the yard should be at least twenty-one days. (In cold weather this method of hardening permits handling a large output with smaller facilities than does steam hardening alone, and is recommended.)

It may appear that an unwarranted amount of space has been given to a discussion of proper hardening methods, but this is a very important stage in the manufacture, since neglect of this final precaution or slighting it in any way is quite likely to nullify the effects of care taken in other steps of the process of manufacture.

Knowledge of what actually takes place in the hardening of cement is still somewhat limited. More complete knowledge of these processes will undoubtedly develop better methods in the manufacture of cement drain tile. However, with the knowledge now at hand, there seems to be no reason why sound tile which will withstand ordinary soil conditions cannot be made; and one would expect that such tile, if properly made and hardened before placing, should become better rather than poorer in the drain. But, unless the manufacturer has facilities for bringing into use all of the best possible materials and methods, he should not undertake tile manufacture, even for his individual use. The investment of labor and material required to place a drain is enough to warn one against the risk of using poor tile. The best are none too good.

In all of the foregoing discussion the recommended practice to be followed in the manufacture of plain concrete pipe and drain tile by machine, as adopted by the American Concrete Institute, has been kept in mind. These recommendations may seem rigid but serve to show that in order to produce a satisfactory tile, considerable knowledge of the processes of manufacture is necessary and that careful observance must be made of a number of important requirements.

DISCUSSION OF THE SAMPLES OF TILE RECEIVED.

Several drainage systems, where failures with cement drain tile had been reported, were investigated and a number of samples from each drain were sent to the laboratory for further examination. Some samples were also received direct from the manufacturers. In the discussion which follows, these samples are referred to by lot number only.

Chemical tests and analyses showed that a portion of the essential constituents of the cement had been dissolved out of the badly disintegrated tile. This made these tile very porous and brittle—the cementing materials being so weak that the small particles could be rubbed off with the fingers. Another interesting fact associated with the disintegrated tile was that the disintegration began on the outside, the interior remaining quite sound until the exterior had practically gone to pieces. In some cases the upper half of the tile showed disintegration while the lower half was sound, and in other cases the lower half showed disintegration while the upper half was sound—depending entirely on whether water percolated through from above or from below. The interior of the tile through which the water flowed showed very little, if any, disintegration.

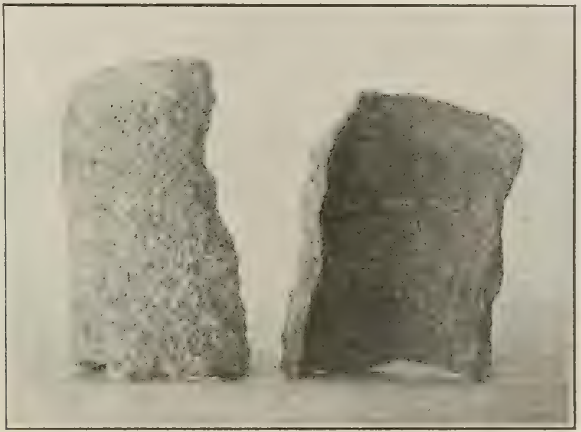


Fig. 3—Exterior and interior views of a badly disintegrated tile showing that the disintegration proceeds from the outside. No signs of disintegration are seen on the inside.

An examination of a sound, unused tile from lot one showed that there was considerably more variation in the aggregate (graded sand) than is usual in good concrete tile, and that the matrix (very fine sand and cement which bind the larger particles together) was very porous. The report giving a brief history of the tile, and the drains from which they were taken, showed that they were "factory made, hauled from the factory as soon as they could be handled, and laid without further curing." They were laid in the spring of 1912 and were removed from the ground in December, 1913.

Some tile left on the surface of the ground near the drain and some of the tile in the drain were in good condition. Others in the drain were slightly disintegrated, and still others almost entirely destroyed.

Other points of interest in this report were that all of the tile laid in clay soil were apparently sound and that of two adjoining tile laid in muck soil, occasionally one was found in good condition and the other badly disintegrated.

From all appearances, the materials used in the manufacture of these tile were of a good grade, but the lack of uniformity of these materials, the porous condition of the matrix, and the fact that occasionally two adjoining tile were found, one of which was sound and the other badly disintegrated, show poor mixing and packing of the concrete. It is also evident that these tile were not sufficiently hardened before laid, and experiments show that this condition may be favorable to rapid disintegration.

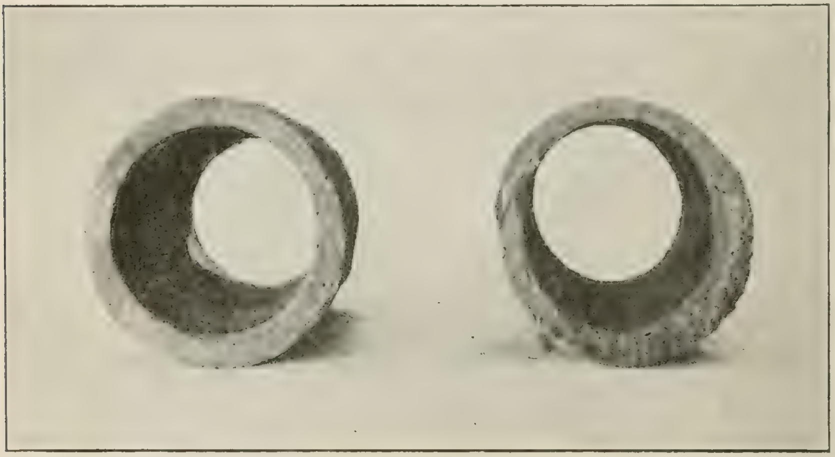


Fig. 4.—End views of sound and partially disintegrated tile, showing that disintegration is usually more pronounced at the top or bottom depending on whether the soil water percolates from above or below.

Samples of tile from lots two and four were so badly disintegrated that no statement can be made as to the cause of disintegration.

Samples from lot three contained a small percentage of particles too large to use in the preparation of concrete tile ½-inch thick. They also contained some organic matter and clay, and probably the worst feature of all was that the material was not properly mixed and packed (there were some spots in the tile wall nearly an inch long where the particles were not in close contact and therefore not cemented together). The matrix of fine sand and cement was very porous and not in close contact with the larger particles. Such tile are weak and easily affected by soil water.

The tile comprising lot five, some of which were made from washed and some from unwashed aggregate, showed considerable difference in density, the finer material being removed in the one case by the washing. None of these had been in place in the ground, but from appearances one would conclude that they were well made and that both would be reasonably durable; although it is evident that the walls of the unwashed sample would be less susceptible to the passage of soil solutions—undoubtedly an advantage in drain tile.

Lot six represents a small piece of tile taken from the yard of a tile manufacturer in one of the larger cities of the State. This sample, though small, was typical of the tile in the yard at that time and was found to be exceptionally porous, the cementing properties being so weak that particles could easily be rubbed off. It does not seem possible that such tile could remain sound when placed in the ground.

Two indications of good quality in tile are high supporting strength and low percentage of absorption. Tile which shows a small percentage of absorption is to be preferred in every respect to that which shows high absorption. In making examinations to determine the absorption it is necessary to dry tile at a temperature of 212 degrees Fahrenheit until they show no further loss in weight. Tile will absorb their full capacity of water within twenty-four hours after immersion. Tests have shown that high strength and low absorption go hand in hand.

BEE-KEEPING BECOMING SPECIALIZED.

Special Bulletin No. 76.

The methods of bee-keeping employed twenty years ago were very unlike those of the present day. Only a few years ago bees were kept for the little honey they produced for family use. The swarm was hived in a box or barrel and was left to work out its own salvation. Disease, when present, was seldom recognized, and when a colony died from disease the loss was attributed to some other cause if, indeed, the cause was

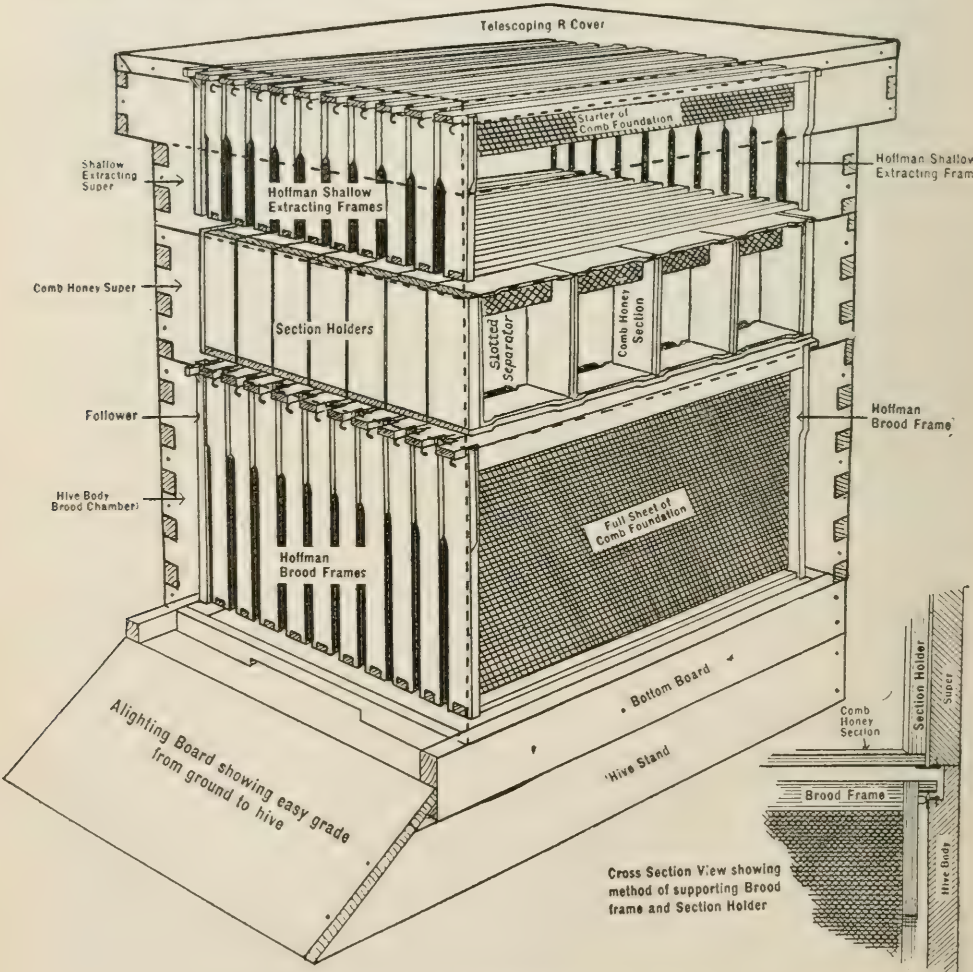

Telescoping R Cover
Starter of Comb Foundation
Shallow Extracting Super
Hoffman Shallow Extracting Frames
Hoffman Shallow Extracting Frame
Comb Honey Super
Section Holders
Slotted Separator
Comb Honey Section
Follower
Hoffman Brood Frame
Hive Body (Brood Chamber)
Hoffman Brood Frames
Full Sheet of Comb Foundation
Bottom Board
Hive Stand
Alighting Board showing easy grade from ground to hive
Section Holder
Super
Comb Honey Section
Brood Frame
Hive Body
Cross Section View showing method of supporting Brood frame and Section Holder

Fig. 1. Modern Hive with Hoffman Frames, after Root.

considered at all. Severe winters killed all but the strongest of those colonies, which were unprotected, and so the bee-keeper would "increase" to a considerable number of colonies, expecting to lose the greater part of them through neglect.

In recent years a new kind of bee-keeper, the specialist, has come to the front and we find the haphazard bee-keeper gradually disappearing, his place being taken by the one who is trying to manage his apiary by modern methods. Bee-keeping is now recognized as one of the special branches of agriculture and those who engage in it find that when one has the necessary experience, the returns compare favorably with those from most other branches of agriculture.

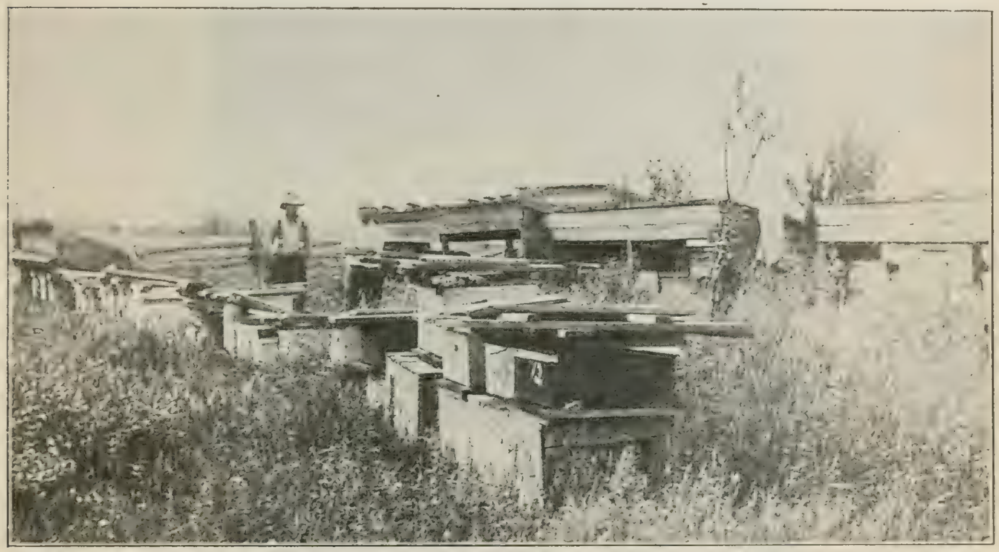


Fig. 2.—A Box-hive apiary (original).

BOX-HIVES.

Despite the progress in bee-keeping there are still many colonies in Michigan kept in box-hives of some kind. By the term box-hive we mean a hive that cannot be examined readily by the removal of the frames containing the combs.

Box-hives should give way to the movable-frame type of hive for many reasons, among which may be mentioned the following:

It is impossible to control foulbrood in box-hives.

Bees in box-hives cannot be managed so that the bee-keeper is master.

The returns, or profits, from a colony in a box-hive are seldom as large as those from a colony in a movable-frame hive.

The keeping of bees in box-hives usually means a neglectful bee-keeper.

TRANSFERRING BEES.

There are many ways by which bees can be transferred from any kind of box-hive into one of the movable-frame type. The bee-keeper should carefully read the following directions and then proceed with the method that best suits his particular case.

THE HEDDON METHOD.

The plan employed by the late James Heddon, a Michigan bee-keeper, is easily followed by the most inexperienced of bee-keepers. When employing the Heddon method the movable-frame hive is made ready with frames of foundation just as one prepares a hive for a swarm. The operator provides himself with a smoker, hive-tool, veil, empty box and a hammer or other tool with which to drum on the box-hive. When ready to transfer, the box-hive should be removed to a place a few feet from its old stand and the newly prepared hive put in its place, ready to receive all the bees that return to the old stand while the transfer is being made.

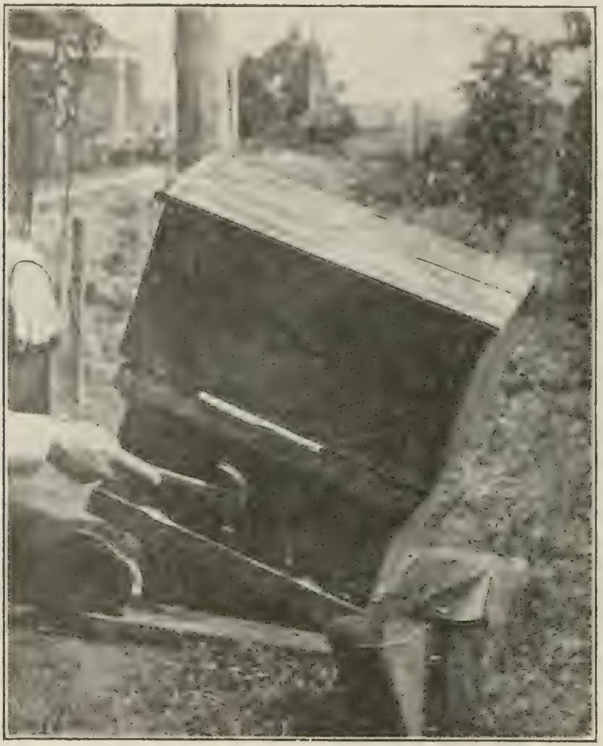


Fig. 3.—Drumming the Bees into Empty Box. Box-hive is tilted and cover removed (original)

When everything is ready pull off a part of the top or cover, and turn the box-hive upside down, tilting it so that the back is a few inches higher than the front. This operation makes it possible to smoke the bees from beneath. Next place an empty box on top and be sure that the box comes even with the back of the box-hive so that the bees have a continuous wall to climb. Smoke the bees from below and drum on the sides of the hive, near the bottom at first. After drumming a few minutes and using the smoker occasionally, a cluster of bees will be found in the box when it is taken off the box-hive. The bee-keeper should search carefully among the bees in this cluster to see if the queen is present; if she cannot be found in the cluster, shake the bees out in front of the new hive on a light cloth or paper and as the bees enter the hive, watch to see if the queen is among them.

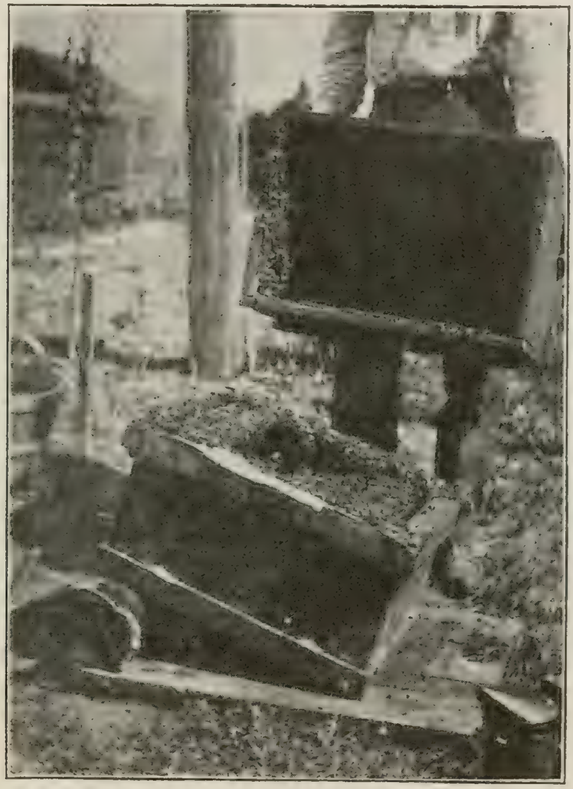


Fig. 4.—A few minutes later a large cluster of bees will be found in the box (original).

To succeed with the Heddon method the queen must be drummed out from the box-hive and introduced into the movable-frame hive. If the bee-keeper is not quite sure that he will be able to recognize the queen, he should place a drone-trap at the entrance of the new hive; in this way he will be certain to find the queen if she is present.

When the queen and about two-thirds of the bees have been drummed out, turn the box-hive right side up, replace the cover and set it on its bottom-board directly behind the new hive, with the entrance at right angles to the entrance of the new hive.

After twenty-one days the worker brood in the old hive will have hatched and the remaining bees can then be drummed out, by the same method as that formerly used. These bees should be united with those in the movable-frame hive. When uniting the two lots, smoke the bees in the new hive a little and they will unite with the new-comers without trouble. There probably will be a young queen among the last group of bees in the box-hive, and if the bee-keeper has any queenless colonies this young queen can be introduced where needed; otherwise take no notice of her and she will probably succeed her mother in the new hive, providing a young queen as head of the colony. After the bees have all been drummed out, remove the combs, extract the honey, render combs into bees-wax and use the box-hive for kindling.

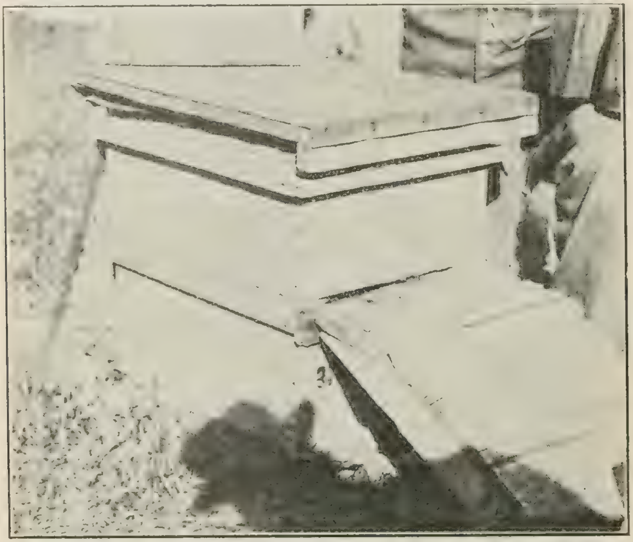


Fig. 5.—Guernsey Method. Bees transferring themselves. Queen above Excluder (original).

THE GUERNSEY METHOD.

Mr. A. H. Guernsey of Ionia, Michigan, uses the following method for transferring bees from the box to the movable-frame hive.

At a time when the box-hive is crowded with bees, usually in May or early June, the transfer is commenced. The bee-keeper provides a hive-body containing one frame of unsealed brood placed midway between a sufficient number of frames of drawn comb or full sheets of foundation to fill the hive-body. The box-hive is then opened and the new hive-body, with brood and combs, or foundation, placed on top. In a few days, usually, the queen will be found laying in the upper, or new, hive-body; but if foundation only is used it may be a week or two before the queen comes up. As soon as the bee-keeper is sure the queen is in the upper hive-body a queen-excluder is placed between the box-hive and the new hive and left there for twenty-one days. When examining for the queen it is a good plan to slip the excluder between the two hive-bodies before disturbing the bees very much as the queen is liable to run below. If, on examination, it is found that the queen has not commenced working in the new hive, the excluder must, of course, be removed and replaced after the queen ascends. Supers may be added to the new hive as required and work proceeds normally. The success of this plan depends on getting the queen to ascend and commence working in the new hive and, after that is accomplished, in preventing her return to the box-hive. After the queen has been established in the upper new hive and when the queen-excluder is in position close up all outside entrances to the old box-hive and provide entrance to the new hive by inserting wedges between the two hive-bodies. A sloping alighting-board, extending from the new entrance to the ground, will aid the bees in making a speedy entrance. Twenty-one days after the queen-excluder is placed between the hives, with the queen above, all the worker-bees will have emerged from their cells in the box-hive.

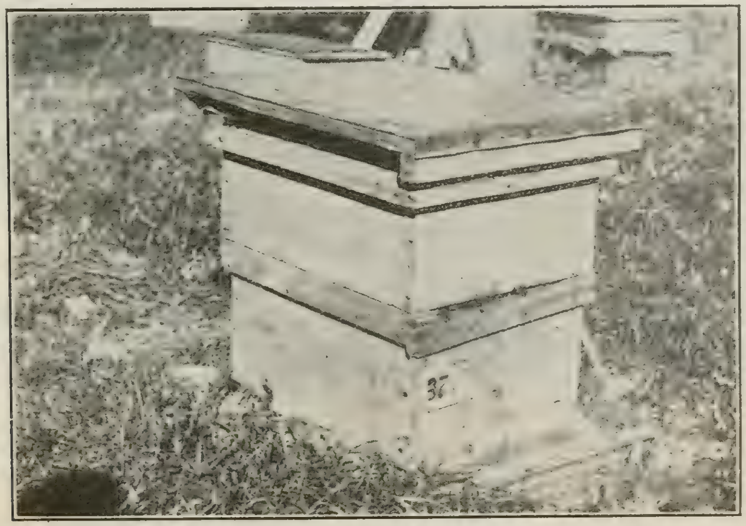


Fig. 6. Month later, bees removed from box-hive and the entrance closed (original).

Prepare an escape-board by tacking a strip of wood just over the edge of the circular hole in the bee-escape. This strip is to aid the bees in climbing up to the Porter bee-escape. Place the board with bee-escape upside down between the hives in place of the queen-excluder. Two days after the escape has been placed between the hive bodies all the bees will have gone above and the old box can be broken up and the combs rendered into wax.

The Guernsey method is one of the best if the colonies are strong and no disease exists. Weak or diseased colonies should be treated by other methods.

THE WATER METHOD.

Sometimes a bee-keeper may buy a few colonies of bees in box-hives late in summer and may not wish to keep them through the winter in the old boxes. If one has combs of sealed honey, surplus from other colonies, it is a simple matter to transfer the bees from their box-hives to hives containing the frames of honey and to winter them in the new hives.

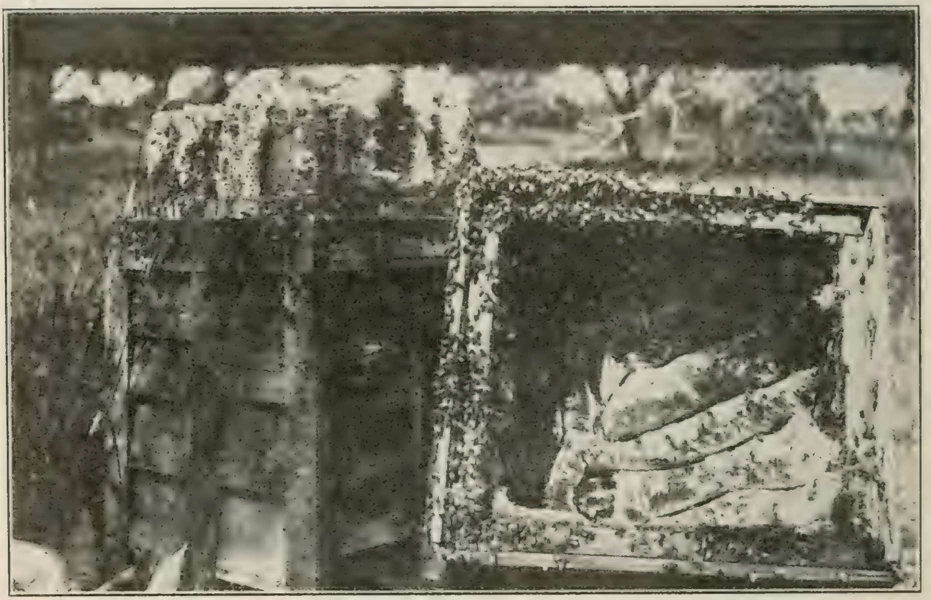
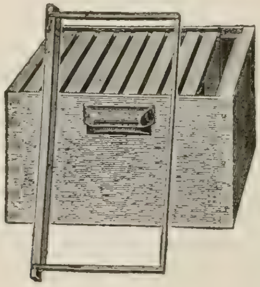


Fig. 7.—A box-hive with honey stored in cover,—Messy and unprofitable (original).

Early in October, as soon as brood-rearing has ceased and when the weather is warm enough for bees to fly, prepare a hive-body with frames of honey. Have ready some receptacle for water, wash tub, boiler or anything that is large enough and deep enough to allow the box-hive



[Fig. 8.—Dovetailed hive-body, after Root.

to be entirely submerged in the water. Then remove the top and bottom of the box-hive, using a little smoke, and place the newly prepared hive-body on the box-hive, making sure that bees cannot escape between the two bodies. While the two hive-bodies are held in contact slowly lower the box-hive into the water until the water reaches its top. The bees will ascend into the newly-prepared hive after which this can be removed and placed on its bottom-board on the old stand. The box-hive can be broken up, the honey removed and the combs rendered into wax. In case disease is present this amounts to the treatment of the colony for disease.

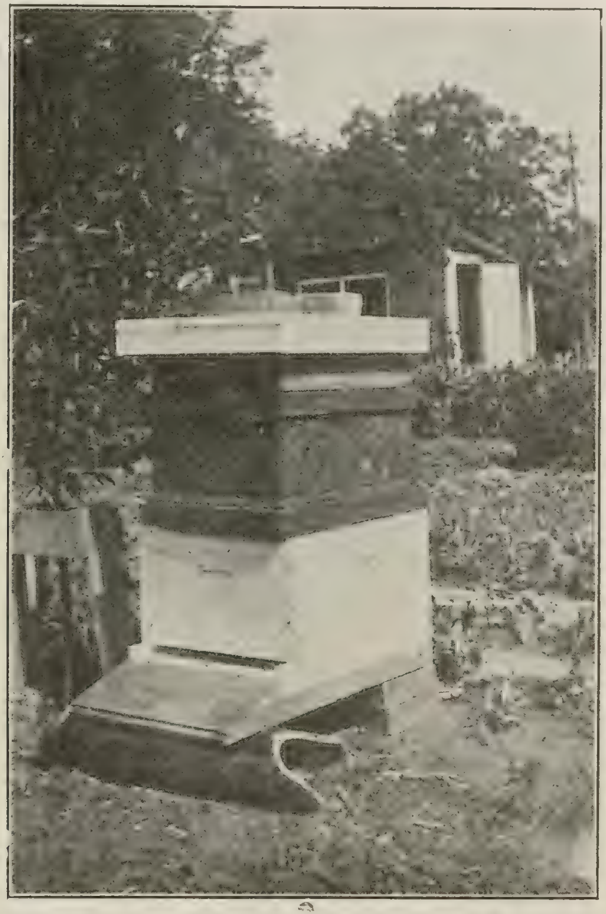


Fig. 9.—Wrong way to transfer. Bees ascend more readily than they descend. Box-hive should be below movable frame-hive (original).

THE DIRECT METHOD.

There are one or two variations practiced in the direct method of transferring but in any case the result is the same, in that all the transferring is completed in the one operation and the box-hive is done away with.

If the bee-keeper is sure that there is no disease present the following method is used: A new hive is prepared with empty frames. There are needed also an empty box into which to drum the bees, a smoker, veil, hive-tool, butcher-knife, large bowl, a board, some fine string and a pail of clean water. Remove the box-hive a few feet from its stand and place the newly-prepared hive where the box-hive stood. This is done to catch the returning bees. Tear off part of the cover from the box-hive and turn it upside down, tilted as in the case of the Heddon Method. Now drum the bees up into the box by continued drumming on the sides and occasional puffing in of smoke at the bottom of the box-hive. After a few minutes shake the cluster of bees from the box, in front of the entrance of the new hive, and continue the drumming until nearly all of the bees are out of the box-hive, uniting these bees with those already in the new hive. When all the bees that can be drummed out are removed from the box-hive, tear the side open, after first cutting the comb away so that it will not be broken when the side of the hive is torn off. With the aid of the board, which should be a little larger than the frame, we are ready to transfer all the good worker combs from the box-hive to the frames. Lay two or three pieces of string under a frame which should be placed on the board, take a piece of the comb from the box-hive and lay it over the frame and with a sharp knife trim the comb until it can be fitted tightly into the frame, secure the combs firmly in place by wrapping the string around them in two or three places and put these frames with the comb into the new hive. The bees will fasten the comb to the frames with wax. In selecting the comb to be transferred take first the worker comb with brood, next the straightest of the empty worker comb and then, if necessary, one or two frames of comb filled with honey. Do not use any drone comb. Fill up the hive with frames of drawn comb or foundation if more frames are needed.

The bowl will receive all pieces of broken comb and the honey in this can be used indoors. Use plenty of clean water and you will not find this method a very sticky one but never attempt it unless you have plenty of water and all the necessary appliances ready.

Some bee-keepers tear the hive to pieces and transfer the combs without drumming the bees out at all. In doing this they destroy a great many bees and the operator cannot work nearly as rapidly when there are so many bees crawling around. It is better to drum all the bees out first.

The direct method has an advantage over the Heddon and Guernsey methods in completing the whole of the transferring at once and in saving the best of the old combs. If the combs in the box-hive are not too old this is quite a saving to the colony as it is not necessary to build so much new comb. The old box-hive should be removed and destroyed on completing the transfer.

TRANSFERRING FROM BARRELS, HOLLOW LOGS, ETC.

When the bees are housed in a barrel, a section of hollow log or other make-shift for a hive, which, on account of its form, may not lend itself easily to one of the methods just explained, the following plan is recommended:

Remove part of the head or top of the barrel and turn it upside down, saw the barrel off close to the combs and tilt as in the case of the box-hives. Elevate the new hive so that the bottom-board is even with the upper edge of the barrel. Blow smoke in at the bottom of the inverted barrel and drum on the sides, blowing in occasional puffs of smoke, until all the bees have run up into the new hive. See that the ends, or edges, of the combs in the barrel face the entrance of the hive and are not turned broadside. The bees between the combs will not linger so long if the smoke gets between the combs quickly and the bee-keeper standing opposite the entrance can watch the progress more easily.

After the bees have been drummed out and the new hive set on the stand where the barrel formerly stood, the best combs in the barrel can be used in frames, as in the case of the direct method, providing the bee-keeper is certain no disease exists. If the combs in the barrel are not more than a year old greater care has to be taken, because newly-built combs crush very easily in warm weather, especially if heavy with honey. In drumming bees from boxes or barrels in which there are recently built combs it might be well to separate each comb from its neighbor with one or two wads of paper, so that they will not fall together. This also insures room for the bees to pass up easily.

TRANSFERRING FROM BUILDINGS, BEE-TREES, ETC.

Sometimes a colony of bees will hive itself in a hole in a building or in the cavity of a tree which for some reason cannot be laid open. Whenever a swarm occupies a place where none of the preceding methods can be used we must proceed in a different manner. The combs and a few of the bees must be sacrificed but the honey and almost all of the bees can be saved by using the following method:

At the commencement of the main honey-flow build a platform large enough to hold a hive of bees and strong enough to hold a heavy surplus of honey, if honey should be found. Make a nucleus, a two-to-four-frame colony, with queen. In making the nucleus the bee-keeper will have good success if he proceeds as follows: Take from two to four frames of sealed hatching brood without bees and introduce a queen; screen the entrance of the hive and place the nucleus in a dark, cool place for two or three days. This allows a great many young bees to hatch and these young bees are not inclined to fight strange bees nor will they leave their new location when placed on the new stand. When the nucleus is ready to be placed on the platform fill the empty space in the hive with frames of foundation. While the bees are in the cellar set up the platform so that the entrance of the nucleus hive will be very near the flight-hole of the bees in the cavity from which they are to be removed. Cover the flight-hole with a board having a hole in the center large enough to insert a double Porter bee-escape. Place this board so that the bees can leave and enter the cavity only through the small central hole and leave the hole open for a day or two before fastening in the bee-escape so that the bees will become used to the changed condition. Search out all other flight-holes and close them. To be successful with this method all other exits must be closed. After a day or two place the double Porter-escape in the hole, so that the bees can leave the cavity but cannot return to it. In a short time these bees will unite with those in the nucleus and become a strong colony. Leave the bee-escape in the hole for about a month or six weeks and until there is a break in the natural honey-flow. Then remove the escape and suffocate the few remaining bees in the cavity. This can be done by using flour of sulphur in the smoker or by pouring in some carbon disulphide. If the disulphide is used it must be kept away from all lights and fire. It is harmless if the vaporized liquid is not breathed, nor ignited by strong heat, but an explosion is very likely to take place if precautions are not observed. After suffocating the bees leave the escape in the hole until all fumes have escaped, then remove the escape from the hole and in a short time the bees in the hive will find the honey and completely rob out the old combs. When the bee-keeper allows the bees to take the honey out he should be sure he has enough supers on the hive for all the honey there is in the cavity. If the cavity is large and a strong colony has had possession of it for a few years there may be a large quantity. After the bees have ceased entering the cavity the board should be removed and the entrance closed with cement or other material so that bees will not find lodging there in the future. The hive may be left on the platform until fall or it may be removed to the apiary. Move it when the bees are not flying and when there is no honey-flow, or many of the bees may return to their old stand.

In districts where foul brood is prevalent the bee-keepers should cement all holes in buildings or trees where bees are likely to hive themselves. He should also remove the bees already occupying such places.

TRANSFERRING DISEASED COLONIES.

Whenever the bee-keeper has bees suffering from foul brood in box-hives he must modify his method of transferring. There is only one way in which he can proceed with any degree of success. All the bees must be drummed out as by the direct method. A new hive with frames having full sheets of foundation should be prepared and placed on the stand formerly occupied by the box-hive and the drummed bees should be shaken in front upon newspapers weighted down at the corners. Great care should be taken that none of the honey from the box-hive is spilled on the ground or more infection may follow. Remove the box-hive and burn; this removes any possibility of the bees gaining access to the germ-laden honey. After all the bees have entered the new hive remove and burn the paper.

WHEN TO TRANSFER.

Naturally, the bee-keeper will inquire when is the best time to transfer bees. The experienced bee-keeper knows that with proper precautions he can transfer almost at will. The bee-keeper with less experience, however, would probably get into trouble unless he transferred his bees at a seasonable time. The best time is at the beginning of a good honey-flow. At this time the bees can be handled more easily and the probability of robbing is reduced to a minimum.

If the honey-flow should suddenly cease after a transfer has been made it would be well to feed for a few days until the honey-flow begins again. In ordinary seasons the bees should secure enough stores to carry them over any break in the flow.

The bee-keeper is advised to read each method carefully before deciding on which to follow and then, when he is sure of the directions, to make all preparations before beginning operations. He will then find that transferring bees is a simple and a profitable undertaking.

THE SEPTORIA* LEAF SPOT DISEASE OF CELERY OR CELERY BLIGHT.

Special Bulletin No. 77.

BY G. H. COONS AND EZRA LEVIN.

HOW TO TELL THE DISEASE.

Septoria leaf spot or "Blight" shows first as brown, dead spots on the leaves. These spots are soon specked with dots which, though small, are easily seen with the naked eye. (See frontispiece.) With light attack there may be only a few spots on the leaves, and the celery bunches are only slightly disfigured. In a weak market, buyers cut the price 5 to 10 cents per crate for this condition of the tops. However, with severe attack, the leaves wither and die, and the stems merely shrivel and fall down. The disease begins on the older, outer leaves, passes to

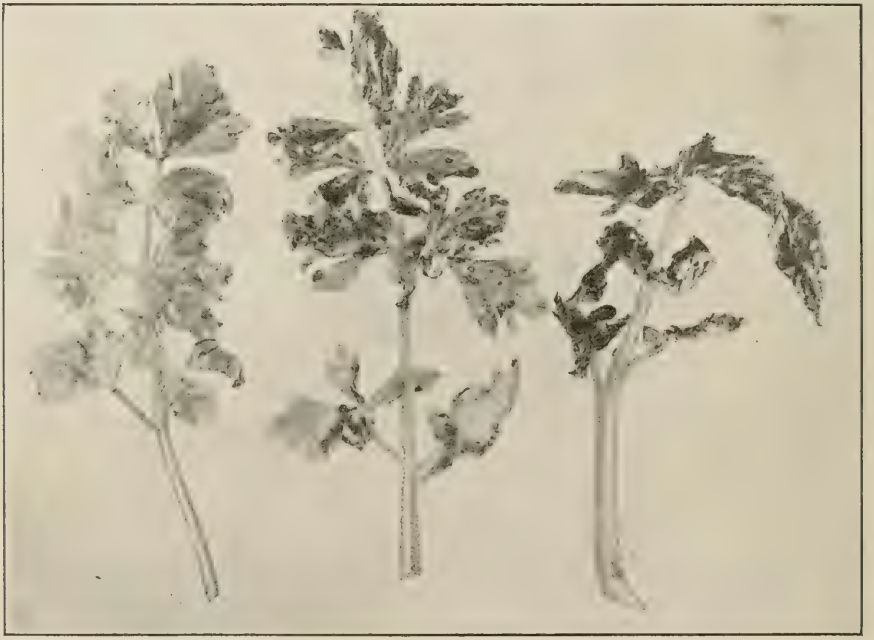


Fig. 2. The diseased leaves in early and late stages.

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*Called Septoria leaf spot because the disease is caused by a fungus, *Septoria apii*.

the inner and heart leaves, until no salable part is free from the trouble. The rotting celery has a characteristic odor. Severe attack means worthless celery, since the bunches will not keep in market or storage.

THE CAUSE OF CELERY LEAF SPOT.

Celery leaves show such spots and the stems rot because of the attack of a parasitic fungus. *A parasitic fungus, or mold, is a small plant that steals its living from another plant.* These parasitic fungi consist of threads so small that a miscroscope is necessary for one to see them. The threads of this fungus twine between the leaf cells and feed upon the cell substances. Just as the larger plants are spread by seeds, these microscopic plants are spread by small bodies which do the same work as seeds. *These bodies are called spores.* The spores of the celery leaf spot fungus are needle-shaped and are only about 1-250 of an inch long. They cannot be seen with the naked eye. These spores are produced in immense numbers inside the black bodies found on the diseased spots on the leaves.

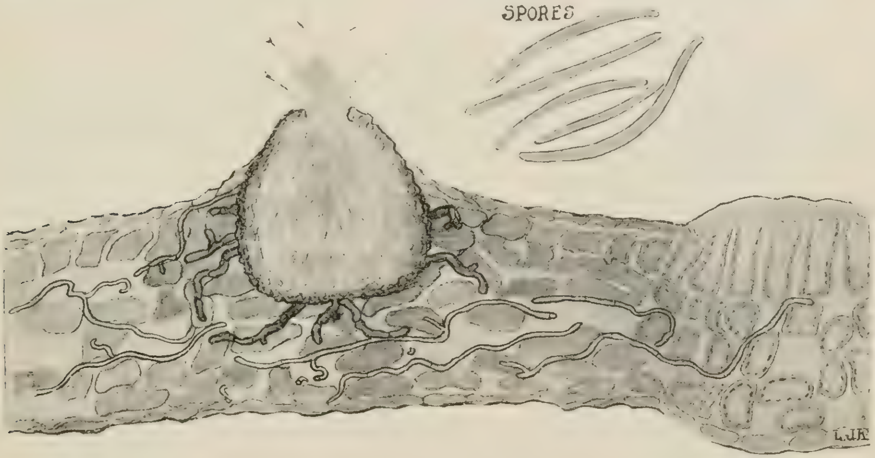

Fig. 3. Section through diseased spot, showing fungus threads penetrating leaf tissue and spore case with exuding spores; enlarged view of spores at right. (Diagrammatic.)

The spores are sticky and when the diseased leaf is wet they ooze out of the black spore case. These spores float about the leaf in the dew. The chief spreading comes from the washing and splashing by rain. When the leaves are dry the spores dry down. Therefore, the fungus spreads only when the leaves are wet.

When a spore (compare with a seed) is washed to a leaf and the leaf stays wet long enough (several hours) the spore sprouts by sending out several tubes. These sprouts grow into the celery leaf and continue to grow inside by sending threads through the tissue. After about nine days (varying with the temperature) a well-marked spot may be seen on the leaf. In about 15 to 20 days the spots show many black spore cases and a second crop of spores is produced. In this way one spore produces, in less than three weeks, millions of others, each of which is capable of producing millions more. It is little wonder that fields can be completely blighted.

WHERE THE FUNGUS COMES FROM EACH YEAR.

The fungus lives over winter on the trash from diseased plants. Nearly all samples of celery seed carry the fungus. The old seed hull is carried above the ground by the growing leaves, and spores from diseased seeds wash to the young leaflets. In this way some plants in the seed bed may have diseased spots and carry the fungus to the field. A few heart leaves may be infected by splashings of rain from the trash of last year's crop.

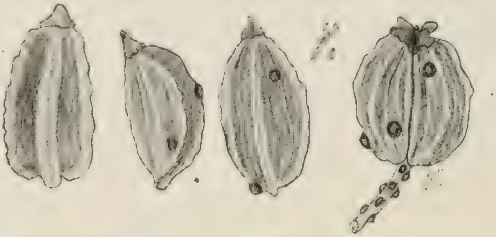

Fig. 4. Celery seed showing fruiting bodies of the fungus; seed at left, healthy.

HOW THE DISEASE SPREADS IN THE FIELD.

The spores from these diseased plants are splashed by rain down to the heart leaves and to neighboring plants and thus a "nest" of the disease arises. *Cultivation when the plants are wet will spread the disease along the row.* The spores are not killed by several days drying, so that when spread they may remain alive until the leaves are wet again. A heavy dew that is slow drying, may keep the plants wet long enough to allow the spores to sprout and get into the celery leaves. Fields that are sheltered from the wind, or poorly drained, or with rows extremely close, invariably suffer most from this disease. *Any condition that keeps the plants from drying quickly or causes the soil to stay wet long favors the leaf spot.*

SEPTORIA LEAF SPOT AND THE WEATHER.

Many growers believe that the weather causes this disease. If this were true we could not hope to do anything to fight the disease, since we cannot control the weather. *The fact is, that without the fungus, no matter what the weather, we would not have this disease.* The proof of this is simple. If we put two healthy celery plants under wet conditions and on one put some spores of this fungus, while the other is merely kept wet, *only the plant with the spores becomes diseased.* If wet conditions caused the disease, both should become sick. Wet weather makes this disease severe by allowing the spores to be spread over the field and by giving the right conditions for the spores to sprout and bore into the plant. Weather does not cause this kind of a plant disease. *Growers must learn to get a crop in spite of the weather.*

HOW TO FIGHT CELERY BLIGHT.

Disinfect the seed before planting. Soak the seed ½ hour or longer in warm, but not hot, water. Then soak ½ hour in corrosive sublimate 1 *part to 1000 of water.* This solution, already prepared, can be obtained from the druggist at about 10 cents a pint. It can be made by dissolving 4 small (or one large) corrosive sublimate antiseptic tablets in a pint of water. *Corrosive sublimate is deadly poison. It must not be used in metal dishes. Keep the solution or the tablets out of the reach of children.* Corrosive sublimate may cut down germination slightly.

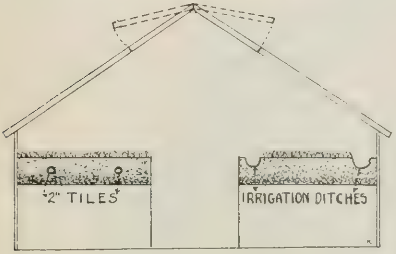

Fig. 5. Diagram of greenhouse showing at left 2-inch tiles placed for sub-irrigation, and at right two small ditches through which water can be flooded.

Spores are usually dead on seed two or three years old. *The use of old seed of good germinating power is to be advised.*

Irrigate the seed beds by gently flooding or place tile for the sub-irrigation. *Do not water heavily.*

If land enough is available, *rotate crops.* This method is best for the land, keeps down weeds, and is the cheapest and best way to fight all celery diseases. Put new, clean soil in the greenhouse—don't use old celery soil*. *Rotate the seed bed,* but do not put it where celery stood the year before. *Do not mulch the seed bed with old celery tops.* Leave no celery trash about in the seed beds.

Cultivate the dirt away from young celery plants so as to expose the crown. This allows the leaves to spread and helps to keep the heart leaves clean.

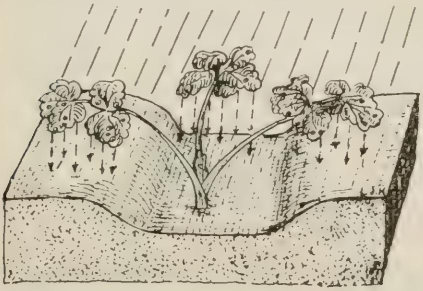

Fig. 6. Right way to cultivate: Dirt thrown away from plant, crown exposed. The drip from the leaves does not fall into the heart.

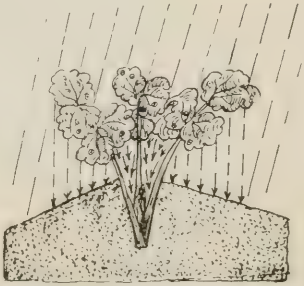

Fig. 7. Wrong way to cultivate: Dirt banked up on young plant. The drip from the leaves falls on the young heart leaves.

Do not work plants while the dew is on or directly after a rain. To do this carries the fungus along the row on the cultivator or on the worker's clothes.

Drain the land well. Keep the ditches clean. Do not locate celery fields in hollows or in places surrounded by trees or buildings. Do not pile boards so as to shelter the rows from the wind. *Ventilation is essential for quick drying.*

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*Old greenhouse soil can be made safe by steam sterilizing. Chemicals to drench the soil may also be used. Use formaldehyde 1 gallon to 50 gallons water. Pour on as much as the soil will hold (about a gallon to the square foot). Stir the soil thoroughly as the chemical is applied. Cover with paper or canvas over night. Then work the soil each day till it dries and the fumes escape. From three days to a week will be necessary to get the soil into shape. All boards, paths, tools, etc., must also be drenched with the disinfectant. *This treatment of greenhouse soil is aimed more at soil diseases than at leaf diseases.* Two gallons formaldehyde (cost $2.00) will treat 100 square feet.

Spray the celery plants every two or three weeks with home-made Bordeaux mixture prepared *exactly* according to directions. *Spray oftener if the season is as wet as the past one.*

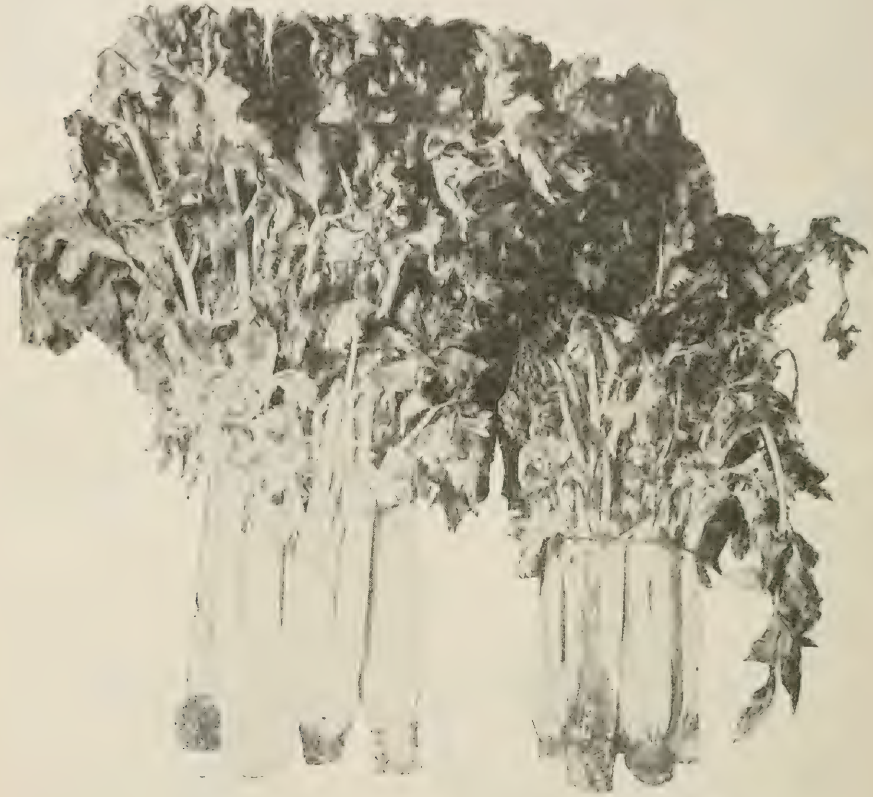

Fig. 8. Sprayed and unsprayed celery from the Muskegon experiment.

Bordeaux mixture is a preparation poisonous to fungi and is used to give plants a protective coat. It is simply a *dilute* solution of Bluestone (or Blue Vitriol), 2%, mixed thoroughly with a dilute milk of lime (2% Stone Lime), applied at once.(Fig. 9). The Bordeaux must be on the plant before the danger period. Therefore spray before rains. The Bordeaux, if allowed to dry for a half hour will not wash off. Use home-made Bordeaux, since it is cheaper and better than the commercial product. Celery does not need any lead arsenate or Paris Green. *Lime-sulphur is worthless for celery*—the blight spores can grow in this spray.

A leaf sprayed once is protected as far as the Bordeaux reaches. The leaves increase in size, thus exposing new, tender surfaces. New leaves keep coming. *To protect the new growth, spray often.*

For 1 or 2 acres a knapsack sprayer will do (cost about $5.00). A barrel pump (to run on boards) will cut down the work of spraying. This requires one man to pump and one to spray. (Cost about $50.00). Large acreages should have a *traction* or power sprayer (cost about $100.00 and up). The higher the pressure the finer is the mist produced, and the better the protection. *A small sprayer is better than none.*

The College experiments of last summer at Muskegon demonstrate the value of spraying. The crop of celery harvested from the experimental field was the only celery of good quality harvested about Muskegon last fall. (Fig. 8). The following is the report of Mr. Joldersma, on whose farm the spraying was done:

One-sixth acre (from which accurate returns were kept) sprayed with a knapsack sprayer at a total expense of $2.00 for labor and material gave 125 crates (10x10) fine quality at $1.00 value	$125 00
A similar unsprayed area gave 18 crates poor quality at 50c	9 00
Excess return of sprayed plot	$116 00
Cost of spraying	2 00
Net gain	$114 00

On the rest of the acreage, at an expense of not more than $12.00, Mr. Joldersma saved a crop valued at about $1500.00.

Mr. T. F. Spellman, Decatur, Mich., reports

Sprayed six acres with a horse-drawn traction sprayer, using 40 pounds Blue Vitriol and 40 pounds lime. Labor account was not kept, but was probably not more than $25. 11 cars (about 2000 crates), celery receipts	$2195 55
Total expense—seed, fertilizer, spraying, total labor F. O. B. cars	440 98
Net value of crop	$1754 57

No check was run on this test, but from the fact that the crop about Muskegon, Kalamazoo and Decatur was almost a total loss, and from the appearance of the fields nearby, it seems safe to attribute the excellence of this crop to the spraying.

Spraying and other practices outlined in this bulletin, in spite of cost, must be made a part of good celery growing.

Bluestone is high priced this year and hard to obtain at any price. Nevertheless, celery diseases must be fought if the grower is to be sure of a crop each year. Blight does not come every year but no one knows when the next outbreak will come. As a matter of safety the grower should follow the instructions given to *insure* a crop in spite of bad weather. *The saving of one crop will pay for 20 years spraying.* The Michigan Agricultural College will answer questions on celery diseases and will diagnose specimens *free of charge.* We invite correspondence on celery disease problems. Address Department of Botany, Experiment Station, East Lansing, Mich.

HOW TO MAKE BORDEAUX FOR SMALL ACREAGES.

(1) *Saw a 50-gallon barrel (vinegar or oil) and make two 25-gallon tubs.*

(2) *Put 2 pounds of Bluestone* (called also Blue Vitriol or copper sulphate) *in a cloth sack and hang over night in one-half a tub of water* (12½ gallons). Bluestone dissolves slowly. Hang it the night before so that the sack is just under the surface of the water.

(3) *Make a lime paste by slaking 2 pounds of fresh stone lime in one-half pail of water.* Stir this into the half tub (12½ gallons) of cold water. Hydrated lime (comes in sacks) will do but is not so good. Use 2½ to 3 pounds of hydrated if stone lime cannot be had. *Then follow directions of the picture. This method makes 25 gallons of spray.*

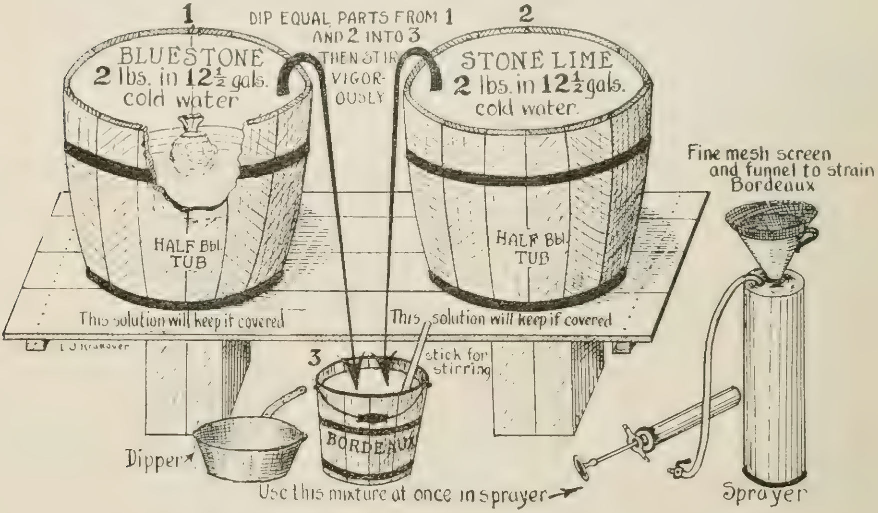
1
DIP EQUAL PARTS FROM 1 AND 2 INTO 3 THEN STIR VIGOROUSLY
2
BLUESTONE 2 lbs. in 12½ gals. cold water
STONE LIME 2 lbs. in 12½ gals. cold water.
Fine mesh screen and funnel to strain Bordeaux
HALF Bbl. TUB
HALF Bbl. TUB
This solution will keep it covered
This solution will keep if covered
L J Kranover
3
stick for stirring
BORDEAUX
Dipper
Use this mixture at once in sprayer
Sprayer

Fig. 9. Good Bordeaux is easy to make if these directions are followed.

NOTE.—Where much Bordeaux is needed, use method of making a strong stock solution by dissolving 25 pounds of bluestone in 25 gallons of water. Make a milk of lime using 25 pounds stone lime to 25 gallons of water. These stocks will keep. Then 1 gallon of stock carries 1 pound of bluestone (or 1 pound of lime). To make 100 gallons of spray, dilute 8 gallons of stock bluestone to 50 gallons, and 8 gallons stock lime to 50 gallons and pour together. Bordeaux may be tested to determine if enough lime is present by means of blue litmus paper. If blue litmus turns red add more lime. *With good lime, using the amounts given, no test is needed.*

CHRISTMAS TREE PLANTATIONS

Special Bulletin No. 78.

BY A. K. CHITTENDEN.

In order to determine the practicability of growing Christmas trees as a farm crop, the Department of Forestry of the Michigan Agricultural College established an experimental Christmas tree plantation at East Lansing in 1909. Sufficient time has now elapsed to warrant definite conclusions being drawn from this plantation.

The area devoted to the experiment was 0.28 of an acre. The soil is a stiff yellow clay very full of medium sized stones from two to eight inches in diameter. The land slopes to the east and a seepage of water from a flat area above causes excessive moisture and a cold soil during the spring months. During the summer the clay dries out and bakes badly. Prior to planting the trees the best top soil had been removed by several years of erosion.

The land was prepared by fall plowing. In the following spring the ground was harrowed, the gullies filled in, and the loose stones removed. There were three harrowings in all. Lastly, a float was used to level and prepare the ground for planting.

A layer of coarse horse manure was plowed under with the fall plowing. No other fertilizer was applied, nor has any been used since as top dressing.

Four year old Norway spruce transplants were used. These trees at the time of planting were about 1.4 feet high, good, strong, sturdy stock. They were planted with a triangular spacing of 3 feet, at the rate of 5,584 to the acre. The marking was done by a horse marker.

The plantation was cultivated three times during the first season. No hand work has been done since the planting. Two cultivations were given the plantation during the summer of 1910. Since that time the area has received no cultivation of any kind. The time required to cultivate the area once over was about 2½ hours for one man with single horse.

Thinnings were first made along the south and west sides where the soil, being much deeper and of better tilth, enabled the trees to grow more rapidly. The two outside rows along these sides were thinned to about every other tree in 1913. The largest trees were taken out and consequently the removal was not entirely uniform. In 1914 further thinning was made generally over the area. Wherever a large tree appeared to be crowding the ones around it, it was removed. About 350 trees were removed in 1913 and 100 in 1914. In 1915 three hundred trees were taken out. All of these trees taken out in thinnings were trees that could be disposed of to good advantage.

The loss in the area from 1909 to 1913, when thinnings were begun, was less than two per cent.

The trees grew rapidly for the first three years, until the roots reached the clay subsoil, when a decided falling off in growth took place. This falling off in height growth at such an early age is not characteristic of the Norway spruce which is one of the fast growing trees. Norway spruce in nearby locations where the surface soil is deeper have maintained a uniform height growth of about one foot per year. It may safely be said that the slackening in growth in this plantation was due to the clay subsoil near the surface.

A Christmas tree 7.8 feet high, grown in 6 years from 4-year transplant stock in experimental plantation.

The following table shows the average growth made by the trees in this plantation since it was established. The first column gives the average height growth of 10 of the largest trees, the second column gives that of 10 of the smallest trees, while the third column gives the average of 320 trees taken in consecutive order through the plantation, and is a fair average of the whole.

HEIGHT OF TREES IN PLANTATION.

	Average of 10 largest trees	Average of 10 smallest trees	Average of 320 trees
	Feet.	Feet.	Feet.
Height of transplants	1.8	1.4	1.4
1st year	2.7	1.7	2.1
2nd year	4.0	2.3	3.0
3rd year	5.7	2.9	4.1
4th year	7.2	3.2	4.9
5th year	8.4	3.4	5.5
6th year	9.5	3.6	6.0

There are now 800 trees left in the plantation. The number and percentage of these trees by 2-foot height classes, as they would be put on the market, at the close of the year 1915 were as follows:

NUMBER OF TREES IN PLANTATION BY HEIGHT CLASSES.

Height class, feet	Number of trees	Per cent.
2-4	77	10
4-6	474	59
6-8	200	25
8-10	49	6

These figures do not represent what the plantation would have produced as the 750 trees which were taken out in thinnings were nearly all the larger trees.

For Christmas tree purposes too rapid growth is not desirable. If the trees grow faster than one foot a year they become spindly. The best Christmas trees are those which have grown rather slowly. They are bushier and better shaped than very rapidly grown trees.

For a land owner who is located near a good market, the growing of Christmas trees promises to be a profitable industry. There is a steady although limited demand for such trees. Christmas trees are now obtained principally from the forests, usually at a considerable distance from the cities. They are shipped by the carload from the spruce and fir forests of Michigan, New York and Vermont, and with the depletion of the forests of the country the supply of small trees for this purpose will probably decrease.

Christmas trees can be grown on any farm in Michigan. Norway spruce is the best tree to plant for this purpose. It will do well on almost any soil of good tilth. It grows rapidly, the branches stand out well from the main stem and it makes a beautiful tree. The best size for Christmas trees, the size for which there is the greatest demand, is from four to eight feet tall. Such trees can be grown in five to six years if good strong transplants are used. The prices for Christmas trees vary, of course, with the locality and other factors, bringing, wholesale, from 15 to 40 cents apiece. It is reasonable to assume that a tree four to six feet tall will bring a price, wholesale, of 15 to 20 cents and a tree six to eight feet tall, 20 to 25 cents.

A few of the more rapidly growing trees in the plantation. Note the poor shape of the faster growing trees, the one on the left and one of those near the center.

In setting out a Christmas tree plantation it is best to use good strong transplants, such as may be obtained from forest nurseries. There is considerable difficulty attached to raising the trees from seed, but if transplants are used this difficulty is avoided. The seedlings grow very slowly for the first two or three years and need considerable attention, but after they have been once or twice transplanted, as would be the case in good nursery stock, they grow rapidly.

Four or five year old transplants are best. Such stock should be from ten to eighteen inches tall. The trees should be planted with a triangular spacing of three feet each way, requiring 5,584 trees to the acre. If, instead of planting with a triangular spacing, a rectangular spacing of three feet is used, 4,840 trees will be required per acre.

The best time for planting is in the spring as soon as the snow is gone and the frost is out of the ground. A regular spacing should be used as it makes cultivation easier and the trees will have uniform growing space and will be more shapely. In planting, two men work together to best advantage, one man to dig the holes and the other to carry the trees and plant them. The holes should be slightly deeper than is necessary to take the roots when spread in a natural position. Fine moist earth should be sprinkled over the roots and the coarser soil drawn in next and packed firmly with the foot. A layer of loose soil should be scraped around the tree in order to retain the moisture. Great care must be taken in handling the stock in the field to see that the roots do not dry out. They should not be exposed to the sun or wind. It is a good plan to keep a piece of wet burlap over the roots when moving the plants. The roots should be thoroughly puddled just before planting, that is, dipped in a thick mud of such consistency as will stick to the roots.

The plantation should be cultivated occasionally for the first two years, to keep down the weeds and prevent early surface rooting and evaporation. Such cultivation will pay for itself in increased growth. After the first year the trees should grow about one foot a year. When the trees are about four feet high, which, if four-year transplants are used, will be in four years, they may be thinned out in order to prevent their crowding each other. By thinning them out the remaining trees will have more room to develop side branches and intermediate returns may be obtained from the trees taken out. This thinning is not necessary, however, as the trees will not crowd badly for some years. The degree of thinning should depend on the market for small sized trees. If it is good every other tree may be taken out. In making these thinnings the larger trees should be taken out, so as to give the remaining trees more growing room, and because the larger trees can be disposed of at a better price.

Four to five year old transplants can be obtained for about $15.00 per thousand. Planting 5,584 to the acre, the cost for the stock would be $84.00 per acre and the cost of planting the trees should not be over $40.00 per acre, or a total cost for stock and planting of $124.00 per acre. Cultivation is not a large item and can be done in spare time, being required only occasionally. Figuring the loss in the plantation at 5 per cent, 5,305 trees will reach salable size. At the end of four years a considerable number of the trees will be large enough to put on the market, probably sufficient to pay for the investment if desired. In an operation of this kind the money invested should be figured at the local rate of interest which could be obtained, say 6 per cent. The following statements show the returns that may be expected, using the above data for a basis, and neglecting interest charges on the value of the land.

Assuming an average price of 15 cents per tree with a 5-year rotation

5,305 trees at 15 cents........................	$795.75
Stock and planting, $124 at 6% for 5 years......	165.94
Balance	$629.81

This balance of $629.81 is the difference between the receipts obtainable at the end of the 5-year rotation and the total cash investment in stock and planting costs, together with compound interest at 6 per cent for the five years. In other words assuming that the farmer had to borrow the money to buy the stock and do the planting, this balance is the amount that he would have left at the end of five years if he then paid back the borrowed money with compound interest at 6 per cent, and this would be equivalent to his holding a mortgage which paid 6 per cent interest and which gave him a yearly income of $111.73.

If a 6-year rotation is used, the trees will be larger. Assuming an average price of 20 cents per tree, the results would be:

5,305 trees at 20 cents........................	$1,061.00
Stock and planting, $124 at 6% for 6 years....	175.90
Balance	$885.10

which, in the same way as in the previous statement, would be equivalent to an annual income of $126.90.

It may not be advisable to put all the trees on the market at once. This must be governed by local conditions. The growth of the trees will also depend on the soil. Nothing has been said about harvesting the trees and no item has been included for this. The harvesting comes in the winter when work is slack. The trees can be readily cut with a saw. The above figures may be checked by obtaining quotations on Christmas trees, wholesale, from a grocery company or anyone handling Christmas trees in the locality. This should be done before establishing a plantation, and the probable demand for the trees should govern the size of the area planted.

MICHIGAN'S SHIFTING SANDS.

THEIR CONTROL AND BETTER UTILIZATION.

Special Bulletin No. 79.

BY F. HOBART SANFORD.

Sand dunes occur quite generally on all continents. Some of the most prominent are found in Australia, France, Cape Colony, the Great Sahara and in Western Asia and many other places in the old world. Prominent among the dune areas of the United States are those at Cape Cod, along the Coast of California and Oregon, the Columbia River dune region and the Great Lakes Region.

Vast amounts of money have been spent on sand dune reclamation, some to good purpose followed by entire success, and some in the form of experiment. This experimental work has demonstrated satisfactorily the possibility of control. It is no longer a matter of guess although the same methods will not apply in all cases. Dunes which occur near salt water present greater difficulties in their control than those lying inland or near fresh water. The humidity of the locality as well as the total annual and seasonal rainfall all contribute their effects. The Great Lakes sand dunes are favored in this respect. The lake winds are heavily charged with moisture, and the annual rainfall amounts to from thirty-five to forty inches on the Lake Michigan shore and from twenty-six to thirty inches on the Huron and Superior shores. Under such moisture conditions and with the absence of the deleterious influence of the salt spray of other regions successful reclamation of shifting sand may be assured.

The sand dunes in Michigan are found in four belts on the shores of the three greater lakes. These belts are mentioned hereafter as the Superior Belt, meaning the line of dunes found on the Superior shore of the Upper Peninsula; the South Shore Belt, meaning the belt along the south coast of the Upper Peninsula; the West Shore Belt as that formed by the winds and waters of Lake Michigan upon the west coast of the Lower Peninsula; and the fourth, the East Shore Belt as that washed by the waters of Lake Huron.

Geologically the sand dunes are young. They had their origin after the disappearance of the Toledo Wisconsin Ice Sheet or when Lake Michigan attained its present shore lines and they have been formed since by wind and water. That timber has been logged and new forests are again produced proves that the forests have conquered the dunes, and, left alone by man and his agents, the dunes would again be covered with natural forest growth. We cannot now expect this to occur, however, and with the competition for farmland becoming stronger, man has attempted to use the dune areas. A time may come when agricultural science will teach us how to safely use all the sands for agricultural purposes, but until that time comes those lands should produce the crops now known to be suitable to them.

Many examples are found where a dune formation occurs covered with forest and other vegetation. The sand is firmly bound by the roots and masses of vegetative cover. No movement of this sand has occurred for many years. In fact, old forests now stand on and others have been removed from these dunes. During the growth, development, and ripening of this forest there has been no change in the shape or form of these dunes. Such formations are called *established dunes.* With the removal of the timber and other cover from the face of these established dunes there occur breaks in the crust or soil cover. Burnings, cultivation and roadway clearings are the most conducive to these breaks. As soon as a break occurs in a place exposed to the wind, erosion may begin. This wind erosion is often very swift in its action of tearing off the broken crust from large areas and carrying the underlying sand on over the surface and depositing it over the bank or steep slope on the leeward side of the once established dune. (Fig. 1.) Such breaks are called *traveling dunes* and often form a menace to property because of the suddenness of their appearance and activity. Properties have very often been established in the shelter of the established dune and are always more or less menaced by the possibility of a break in its surface.

THE UPPER PENINSULA. THE SUPERIOR BELT. VALUE.

The dunes of the Upper Peninsula do not as yet form a serious economic problem. Until the demand for agricultural land rises to a higher level than at present there is little use in trying to reclaim the waste lands. Their value for summer resort purposes is overshadowed by sites around the inland lakes. Nor is the climate well suited to the handling of small garden farms of fruit, berries or truck. The factors of economic value which warrant the development of the dune lands of the Southern Peninsula's west shore are lacking.

AREA.

Beginning on the St. Ignace Peninsula at Point Aux Chenes and extending for fifteen miles along the shore is the first large active dune region. This belt varies from two to five miles in width and includes the entire west shore of Brevort Lake which is of timber covered or estabished dune formation. The second area reaches from five miles north of Point Patterson to the southwest shore of Indian Lake. This belt is nearly forty miles long and ranges from two to seven miles wide. The third area occupies the central portion of the Garden Peninsula with a shore front on Big Bay De Noc of fourteen miles. An inland or traveling dune occurs on Bay De Noc Peninsula about fifteen miles inland from Peninsula Point and covers an area of approximately four square miles. In all a total area of about 195 square miles or 124,800 acres which should never be used for any other purpose agriculturally than timber production, now lies a waste and nonproductive area.

SOUTH SHORE BELT.

On the south shore of Lake Superior there is another large blow located inland from Grand Marais. This blow is from two to three miles wide and twelve miles long, covering about thirty square miles. A conservative estimate would give the Upper Peninsula about 154,000 acres of sand dune upon which timber should be established and maintained in an unbroken stand. The reforestation and sand control of these two Upper Peninsula belts is largely a problem for the State because the expense required to control and plant these areas will hardly attract private enterprise and capital.

THE SOUTHERN PENINSULA. THE WEST SHORE BELT.

Economically considered the conditions prevailing in the dune regions of the west shore of the lower peninsula are opposite to those found in the upper peninsula. Directly adjacent to the waste dune area lies the great fruit belt of Michigan. Land values are high. Farms are operated intensively. Both rail and boat transportation make the dune belt readily accessible and lying near are large centers of commercial and industrial activity. The problem of dune control here becomes one of private enterprise because of the element of profit which will follow development.

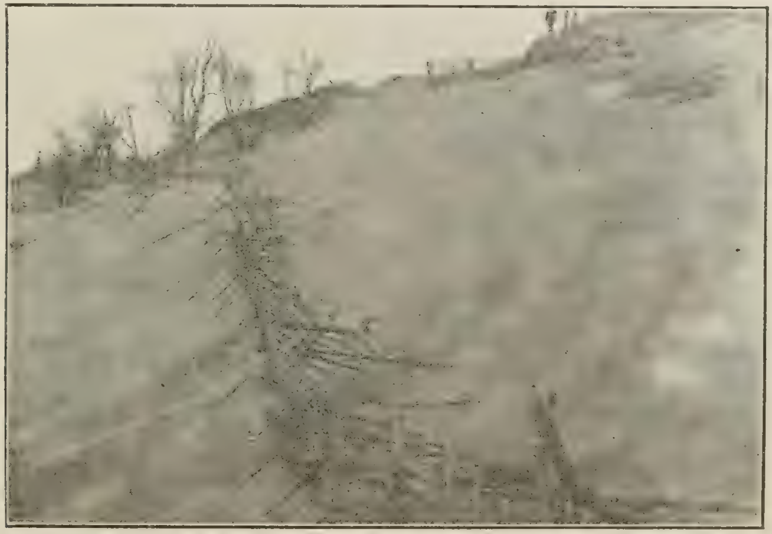

Fig. 1. Many expedients are resorted to in an effort to hold the drifting sand in check. This shows an attempt to form a barrier dune near the foot of a serious break. Without some planting to form a crust at the source of the blow these expedients are of little permanent value. Sand catchers are useful in changing sand drifts and in the removal of sand from valuable land.

Examples are very common along the west shores where large prices have been paid for old established dune lands as summer resorts and summer homes by wealthy people from the cities. Lake Michigan's east shore will one day be as great a pleasure resort as any in the United States because of its accessibility to Chicago and the central south. Its climate is ideal—pure air and ever-constant winds from the lake add to the comfort and pleasure of those who seek rest or health. Adjacent to one of the greatest fruit belts of the world, the prospect of a summer spent amid the dune forests is an alluring one. The State has a duty to perform to its citizens in encouraging the development of this belt of sand. Much of it is too light and shifting to hold any promise of agriculture. Some may be devoted to the growing of fruit if proper protection areas are established, but the larger part, or all of it is capable of producing a second crop of trees which form the chief asset in the development of the people's play grounds, parks, and summer homes. Nor is the economic return to the State of small importance. Attention need only be pointed to the action of several New England States and cities in the development of aesthetic forests to show that it pays. California owes much of her fame to the tourist business and while she has many natural beauties to attract she has developed those other features of orchard and ranch to attract eastern wealth. Prosperous citizens make a wealthy state. Land lying idle is a sign of poverty. Sand lands are not worthless if properly handled. Seldom if ever will the cost of proper handling fail to give an adequate return. Michigan's west shore belt should be developed by covering its sands again with forest growth.

The sand dune land of the west shore of Michigan is difficult of brief description, but roughly speaking it embraces a belt of shore line varying in width from one-half mile to five miles. It extends from the extreme southwest corner of Berrien county northward along the lake coast to Stevensville. It covers two miles of coast along the lake front at Benton Harbor, a belt of sixteen miles north to South Haven, and an almost unbroken belt north from Saugatuck to Whitehall. This is the largest area of traveling and established dunes on the shore, being about fifty-six miles long. Another belt reaches from Little Sable Point to Bass Lake, fifteen miles in length. A belt from Ludington includes Big Sable Lake and shore line to within five miles of Manistee, a distance of fourteen miles, and from Manistee to Portage Lake there is a narrow belt five miles long. There is a belt of one mile at Arcadia and a belt from Frankfort around Betsie Point and along the coast for ten miles to the northeast. It occurs again from Glen Haven and Sleeping Bear Point with a few breaks up at Cat Hand Point. Across Great Traverse Bay the dune area forms a narrow belt along the shore from Elk Rapids to Charlevoix. From Charlevoix it becomes a very narrow belt of about one mile or less in width. Along the shore of Little Traverse Bay to Harbor Springs this belt is generally quite well covered with wild growth of all kinds and is not serious, being of the sand flat type. From Cross Village to Mackinac City the sand area again becomes extensive with frequent active breaks, extending over twenty-five miles of shore line. Approximately 235 miles of the west shore are of dune formation. Assuming that this belt averages one and one-half miles in width of active dune and three miles wide as an average of dune formation there are 352 square miles, one-half of which is shifting sands. The other half is covered with various forms of wild growth. A small part is good selection forest of second growth. Most of it is cut over slash and brush land which is rapidly forming traveling dunes. Some of it, formerly cleared for farm purposes, is now reverting to an abandoned state of pot hole blows and traveling dunes. Altogether a careful estimate places the area fit only for timber growth at 225,500 acres. This forms the facing of the peninsula toward Lake Michigan.

EAST SHORE AREA.

On the east shore a belt ten miles long on Thunder Bay is about one mile in width. From Greenbush to Tawas Beach there is a belt twenty-five miles long and less than one-half mile wide from Greenbush to Au Sable, but over a mile wide from Au Sable to Tawas Beach. From Quanicassee City to Point Aux Barques on Saginaw Bay there is a narrow strip fifty miles long. From Lakeport to Port Huron there is a belt of approximately eight miles. Conservatively estimating the entire dune sand belt of the Huron shore as averaging one-half mile in width gives a belt of ninety-three miles long by three-quarters of a mile wide covering approximately 40,000 acres. Numerous areas have not been considered in these figures.

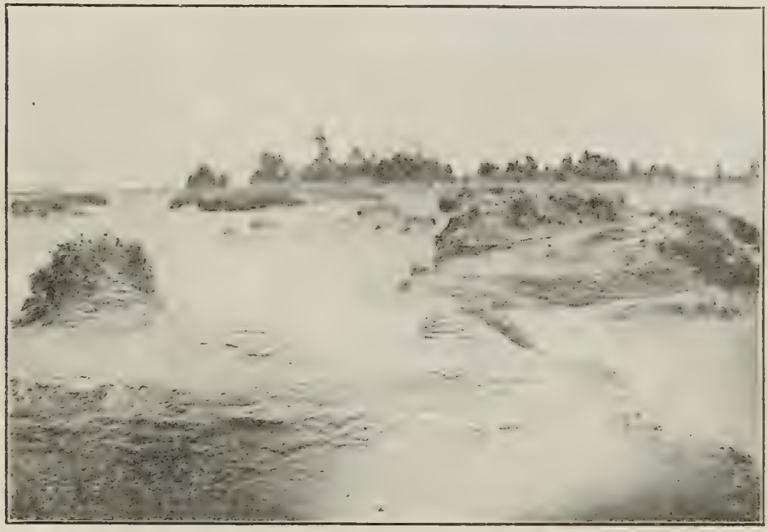

Fig. 2. A condition of crust removal due to wind action, Big Prairie, Michigan. The constant pull of the wind rapidly tears away the vegetable binding, leaving a naked sand swept surface.

INLAND BLOWS.

In various places inland there are large areas of shifting sand. These are not of dune formation. The movement of the sand is irregular. (Fig. 2.) The wind causes blow holes and mounds. Only a few of these areas were studied. The largest one observed is located at Big Prairie and is extensive. No means are being taken to control it because there is apparently no prospect for large financial returns. Where such areas are held privately there should be either one of two plans offered by the State:

1st. Cooperation with the owner in planting with a view toward ultimate forest cover and sand control.

2nd. Purchase by the State at a nominal price followed by reclamation planting.

Such inland areas of extensive proportions should be under State control either through actual ownership or through long term cooperative agreement. Various smaller inland blows occur throughout the southern peninsula, usually only a few acres in extent but nevertheless serious from the owner's standpoint. These smaller blows are readily handled by the owners. Close adherence to the principles of the shelter belt cover system as hereafter outlined will usually insure complete control of these smaller inland blows. No difficulty is experienced in establishing a permanent stand of young forest trees at once by planting. After one year some trees will be blown out while others will be covered up. Often it becomes necessary to use dead cover to protect the planting for the first three or four years. Less than 20% of the trees planted are usually lost in this way.

TOTAL SAND AREA.

Bordering on the Great Lakes, Michigan has at least 534,000 acres of dune formed land. This is stretched out in belts of sand aggregating a total length of four hundred miles.

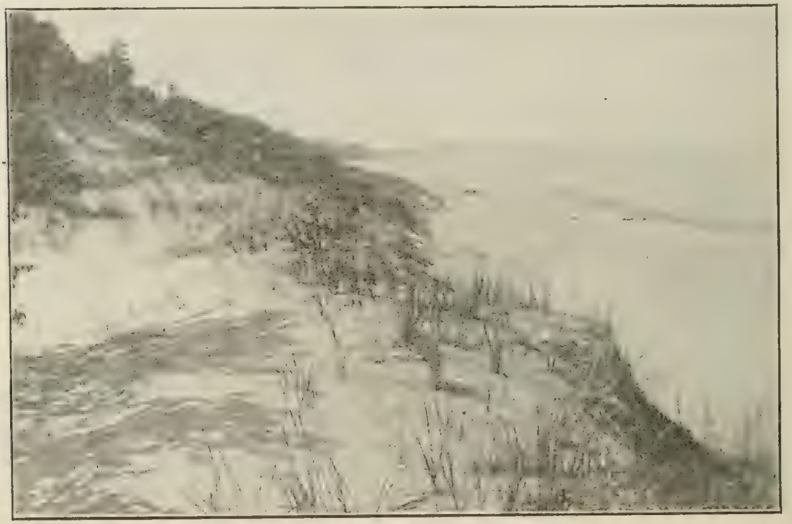

Fig. 3. The point of high water. or the point where the wind catches the sand. The bank of sand is here well planted to beach grass, and must be followed by tree planting. A disturbance or break in this grass cover, made by a foot trail or wagon wheels, is sufficient to make a wind path for the sand which may develop rapidly into a traveling dune.

THEORY OF NATURAL FORMATION OF THE ORIGINAL DUNES.

It is probable that no change has occurred during the process of time in the general formation of sand piles called dunes. The ceaseless action of water, wind and temperature breaks down rocks into increasingly smaller particles and rounds off the angles of the grains. Constantly these grains are cast upon the shore by the waves. The sun's heat soon dries the grains and the wind rolls them higher over the smooth sand surface, finally depositing them with masses of others in drifts and banks on the leeward slope of the newly formed drifts. During this time of wind and water formation of the dune, the vegetative forces are also ceaselessly at work. Here and there reaching above the level sweep of sand surface, portions of rock, driftwood or other debris project. Around these obstacles the wind forms tiny drifts and cuts, into which seeds of sand and shore grasses, and rootstalks of perennials drift and become covered with sand. Growth starts in the shelters thus secured and soon clumps of grass cling tenaciously to the support. (Fig. 3.) Light seeds from nearby trees and shrubs lodge here and gain root. These small spots normally, and annually gain more ground than is lost to natural forces of wind and water. These spots of vegetation and woody cover soon spread over the face of the heaviest drifts and form the crust which establishes the dunes. Species which take part in this early struggle with wind and water erosion, and which gradually win out are all those shore and sand grasses and herbaceous plants which thrive so well on the shores of the Great Lakes. The most prominent and those most serviceable in reclamation are given here and include the three classes of trees, shrubs and plants and grasses which grow wild on the sand dune and drift areas of the State. A complete list is not attempted but only such are given as are most conspicuous in the formation of a cover on the established dune areas.

Many of the shrubs and plants listed form a secondary or soil cover under the canopy of forest trees, and are not directly responsible for maintaining the crust or surface. They do, however, contribute largely in supplying the organic matter, as well as furnish the physical obstruction which is so essential in holding the litter and debris in place against the action of the winds. Many of the species listed are local to one or more of the Dune Belts and this fact should be ascertained before they are generally used.

It is entirely possible that certain plants and grasses found growing in abundance in the Superior Belt may be planted on the Michigan and Huron shores and vice versa, but definite facts should be obtained for each plant so far as possible before it is used extensively.

The following trees grow well on the sand banks and more or less wind-swept shores of the Great Lakes:

TREES.

Conifers.

White Pine	Pinus strobus.
Red Pine	Pinus resinosa.
Jack Pine	Pinus divaricata.
Pitch Pine	Pinus rigida.
Austrian Pine	Pinus austriaca.
Scotch Pine	Pinus sylvestris.
White Spruce	Picea canadensis.
Norway Spruce	Picea excelsa.
European Larch	Larix europea.
Hemlock	Tsuga canadensis.
Balsam Fir	Abies balsamea.
White Cedar	Thuya occidentalis.

Hardwoods.

White Poplar	Populus alba.
Balm of Gilead	Populus balsamifera.
Cottonwood or Carolina Poplar	Populus deltoides.
Large Tooth Aspen	Populus grandidentata.
Trembling Aspen	Populus tremuloides.
Golden Willow	Salix alba vitellina.
Black Willow	Salix nigra.
Black or Cherry Birch	Betula lenta.
Yellow or Bronze Birch	Betula lutea.
White Birch	Betula alba.
Paper or Canoe Birch	Betula papyrifera.
White Oak	Quercus alba.
Red Oak	Quercus rubra.
Black Oak	Quercus velutina.
White or American Elm	Ulmus americana.
Sassafras	Sassafras sassafras.
Beech	Fagus americana.
Silver Maple	Acer saccharinum.
Red Maple	Acer rubrum.
Hard or Sugar Maple	Acer saccharum.
Basswood	Tilia americana.
Black or Yellow Locust	Robinia pseudacacia.
White Ash	Fraxinus americana.

A list of the more common and useful shrubs follows:

SHRUBS.

Ground Hemlock, Taxus canadensis Marsh.
Range: Along east shore of Lake Michigan south to Benton Harbor under forest cover.
Bay Berry (Wax Myrtle). Myrica cerifera L.
Range: Southern Michigan on sandy or sterile soil, near coast.
Sweet Gale, Myrica Gale L.
Range: Borders of ponds, swamps and lakes.
Hairy Willow, Salix adenophylla Hook.
Range: St. Joseph northward on beach sand.
Broad Leaved Willow, S. glaucophylla Bebb.
Range: Lake Shore on beach sand.
Basket Osier, Salix viminalis L.
Range: South Haven. On moist sandy soil.
Three Toothed Cinquefoil, Sibbaldiopsis tridentata (Soland) Rydb.
Range: Barrens of Missaukee County. Grayling and shores of Great Lakes.
Wild Rose, Rosa blanda Aiton.
Range: Along Lake Michigan shore and inland.
Prickley Rose, Rosa acicularis Lindl.
Range: Cheboygan County. Mackinaw City to Petoskey.
Rosa Sayi Schwein.
Range: Northern lower peninsula and southern upper peninsula shores.

Wild Red Cherry, Prunus pennsylvanica L. f.
Range: Very abundant on sandy soil in northern half of State, less abundant south.
Sand Cherry, Prunus pumila L.
Range: Emmet County to Ottawa County. Saginaw County to St. Clair County.
Choke Cherry, Prunus virginiana L.
Range: Common over Michigan on sands.
Dwarf Sumach, Rhus copallina L.
Range: Common in pine lands.
Fragrant Sumach, Schmaltzia crenata (Mill.) Greene.
Range: Bluffs and sandy hills of Michigan.
Wild Winter Grape, Vitis bicolor Le Conte.
Range: Southern Michigan and Lake Shore.
Northern Fox Grape, Vitis Labrusca L.
Range: Muskegon, southward.
American ivy or Virginia Creeper, Parthanocissus quinquefolia (L) Planch.
Range: Common in Michigan.
St. Johns Wort, Hypericum Kalmianum L.
Range: Along the lakes, more common northward, Manistee, Petoskey.
False Heather, Hudsonia tomentosa Nutt.
Range: Sandy shores of Lakes. Frequent on sand dunes.
Canadian Buffalo Berry, Lepargyrala canadensis (L) Greene.
Range: South Haven and northward along lakes. Not found on dunes and dry sand.
Red Osier, Cornus stolonifera Michx.
Range: Marshes and borders of streams, very common on moist flats along Lake Michigan.
Bailey's Cornel, Cornus Baileyi Coult. & Evans.
Range: East shores of Lake Michigan on sand dunes.
Sheep Laurel, Kalmia angustifolia L.
Range: Harrisville west to Portage Lake, Tawas City and Thunder Bay, common.
Dwarf Blue Berry, Vaccinium angustifolium Act.
Range: Dry hills and barrens of Michigan.
Morning Glory, Convolvulus repens L.
Range: General, a good sand bank binder under newly planted shelter.
Button Bush, Cephalanthus occidentalis L.
Range: Swamps and river bottoms. Cheboygan County. Very common southward on moist flats. Soil, swamps.
Partridge Berry, Mitchella repens L.
Range: Beech, maple, hemlock or pine woods, north slopes on pine soils.
Common Elder, Sambucus canadensis L.
Range: Common in clearings and in rich open places.
Sheep Berry, Viburnum Lentago L.
Range: Frequent over southern Michigan, moist flats and in swamps.
Snow berry, Symphoricarpus racemosus Michx.
Range: Along Great Lakes, Saginaw Bay and Alpena County on dry ridges and banks.

GRASSES AND HERBACEOUS PLANTS.

Beach grass, known also as Sea Sand Reed, Sea Matweed and Marram, Ammophyla arenaria (L.) Link. (Fig. 4.) This is the most valuable grass known to hold drifting sand. It is found along all the shores of the Great Lakes and grows vigorously. It is particularly valuable because of its root-stalk growth which enables it to grow up through rapidly accumulating sand.

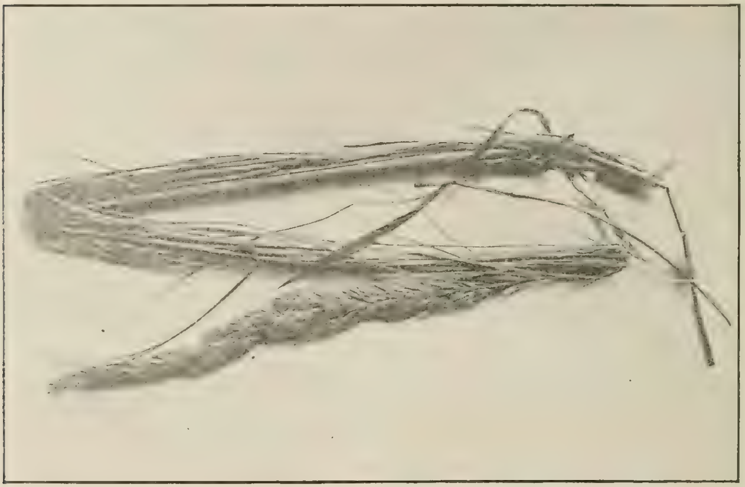

Fig. 4. Photograph of Ammophylla arenaria Link, commonly known as Marram or Beach Grass and considered to be the best of the sand binders.

Long Leaved Grass, Calamovilfa longifolia (Hook.) Hack.
  Range: Lake Michigan and Huron shores.
Sand Grass, Triplasis purpurea (Walt.) Chapm.
  Range: Great Lake's shore. Descriptive photo.
Northern Wheat Grass, Agropyron dasystachyum (Hook.) Vasey.
  Range: Shores of Huron and Superior. Common on dunes of the range.
Squirrel Tail Grass, Hordeum jubatum L.
  Range: South shore of Lake Superior.
Wild Rye, Elymus arenarius L.
  Range: Shores of Great Lakes.
Bristle Leaved Sedge, Carex eburnea Boott.
  Range: Lake Michigan Shore—south half.
Sand Sedge, Carex arenaria L.
  Range: Not a native to Michigan, but probably naturalized from Europe and of promise on account of its vigorous creeping rootstalk.
Seaside Arrow Grass, Triglochin maritima L.
  Range: Great Lakes.
Indian Rice, Zizania aquatica L.
  Range: Sand flats and marshes of Michigan.
Small Rush Grass, Sporobolus neglectus Nash.
  Range: West Michigan shore.

Twisted Willow Grass, Draba incana arabisans. S. Wats.
Range: Along the Great Lakes.

Wild Lupine, Lupinus perennis L.
Range: Sandy soils generally over Lake Region.

The Clovers—Trifolium
- arvense L.
- pratense L.
- repens L.

Rigid Tick Trefoil, Meibomia ridida (Ell.) Kuntze.
Range: Dry soils of Michigan.

Narrow Leaf Bush Clover, Lespedeza augustifolia (Pursh) Ell.
Range: Dry soils of Michigan.

Beach Pea, Lathyrus maritimus (L.) Bigel.
Range: A perrenial decumbent pea vine of great value on the Great Lake Region. It is perfectly hardy and a good spreader.

Sand Violet, Viola subvestita Green.
Range: Throughout Lake Region. Several other members of this genus do well in a partial shade or dry or sandy soils, and should be encouraged.

Fire Weed, Chamaenerion augustifolium (L.) Scop.
Range: Dry soils and comes in readily after clearing and fire. Common over the Lake Region.

Oakes' Evening Primrose, Oenothera Oakesiana Robbius.
Range: Common along the Great Lakes.

Large Purple Gerardia, Agalinis purpurea (L) Britton.
Range: Common on low lying flats along the shores of the Great Lakes but not on the drift sands.

Twin Flower, Linnaea americana Forbes.
Range: On north slopes and cool cover. Not on sands unless shaded and moist.

Beach Cocklebur, Xanthium echinatum Murr.
Range: A coarse sand weed, growing along lake shores and rivers.

White Aster, Frost Weed. Aster ericoides L.
Range: On dry soils of Michigan.

Lake Huron Tansy, Tanacetum huronense Nutt.
Range: On sand dunes of north part of the Southern Peninsula, and north.

Canada Wormwood, Artemisia canadensis Michx.
Range: A perennial root plant growing on sand dunes from New Buffalo to Mackinac City.

Only a small number of plants, grasses and trees of this list form active, aggressive, advance agents of natural reclamation. The rest establish themselves gradually and only after some little protection is afforded by the advance growth.

COVER TYPES.

There are two distinct forms or types of cover to deal with before a final forest cover is established. The first is a temporary type and includes all those hardy persistent aggressive plants above listed. The most prominent being the beach grass, or Marram, the sand pea, the willows, poplars and sand cherries with often a sprinkling of paper birch. These form the temporary type which establishes a crust on the sand drifts. Because of the intolerant character of the foliage of all these plants and further because of their short period of activity and vigorous life, they are not able to permanently maintain the control. Consequently the term temporary type is applied. Fortunately the temporary type fixes the sand and prepares the way for the reception of long lived durable timber trees which are able to find sufficient moisture and form a permanent type or forest. In this way occurs the very gradual reforestation of those great sand shore belts of Michigan.

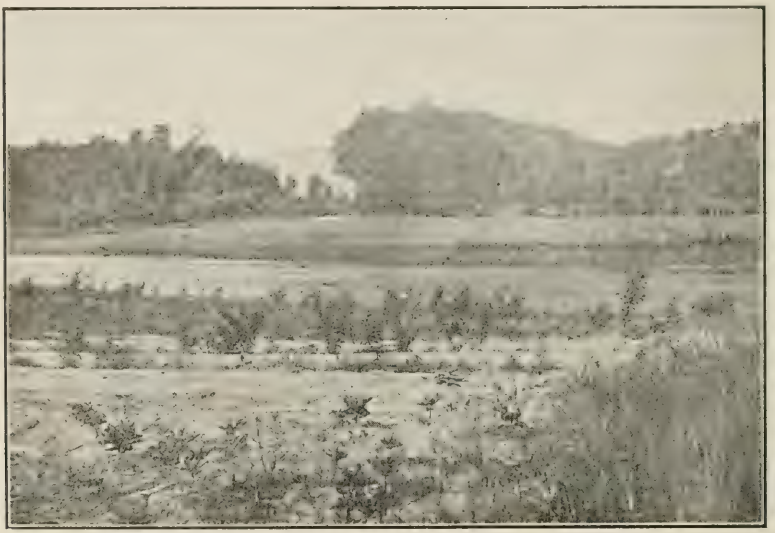

Fig. 5. Break over top of a wooded dune caused by a road which led from the water edge to the top. Wind soon caused the destruction here shown. This dune is burying an orchard.

EARLY CONDITION AND TREATMENT OF DUNES.

When the colonization and settlement of Michigan began early in the eighteen hundreds it seems probable that the West shore was generally covered throughout its length with heavy stands of timber. With the removal of this cover through clean cutting, breaks in the crust occurred. The slash burnings which commonly followed lumbering made extensive tracts as bare as when first formed by wind and water. Construction of roads and clearing into fields help to hasten the formation of the large active or traveling dunes. If nature could be left alone she would finally reclaim the Michigan dunes but this has not been allowed. The sad part of man's interference is that much of the damage done to the natural cover and crust has been unnecessary. Little concern and less care often attended the burning of slash and undergrowth on these sands with the result that the accumulated humus and other sand binders were removed. All chance for a new crop of vegetation was thus destroyed because of the destruction of the seed. Often these burnings were cleared, plowed and cultivated for a few years until nothing could longer be produced. Such handling has prepared the way for heavy shiftings of the original dunes. Repeated cases were studied, which had been caused by early cultivation and later abandoned. Many instances were noted where traveling dunes have encroached upon orchards. In some cases these orchards of full grown trees were either partially or completely buried. In one place in Berrien County a break was caused by a twenty foot road which had been cut over the dune. Through this narrow opening in the timber erosion began by cutting away a clean channel or "slide" until a sweep several rods wide had been eroded clean. This dune was traveling rapidly, estimated at the rate of ten to fifteen feet a year. In this instance a small amount of care and slight expense in planting would have controlled the situation, where now it will require a considerable amount of both time and money before control can be affected. Fig. 5. shows a portion of this traveling dune, taken from the lee or back side.

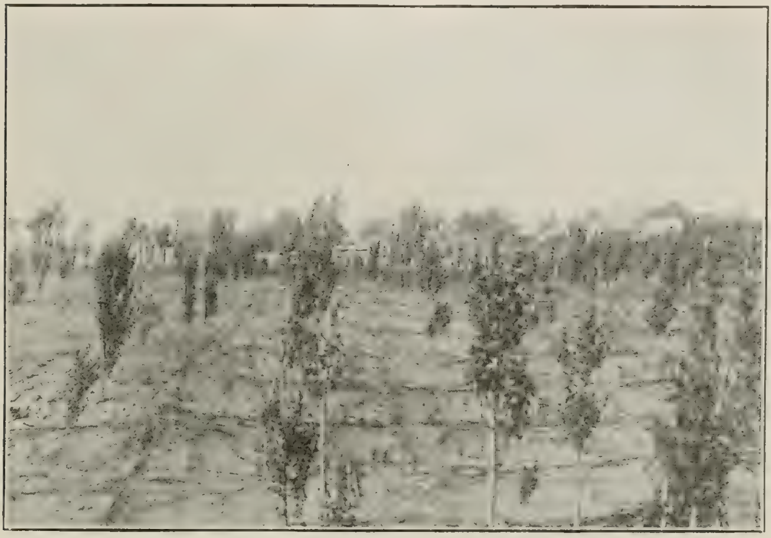

Fig. 6. The planting on Creeping Joe at Manistee as done by the Government in 1902. Poplar was successfully established, a dead cover laid, and grass planted to hold the sand. Blocks were thus well handled but the fault lay in that no permanent planting was followed up.

Owing to the fact that wind is capable of moving only the dry sand grains, and to the further fact that Michigan has a humid climate it becomes possible with care to reestablish the broken or traveling dunes and to permanently control the new ones. The State and the individual have both contributed to the conditions of sand erosion. Thousands of acres of land now lie a total waste, which may produce timber. The dunes annually bury or threaten to bury much valuable property if not controlled. The protection of property now entails heavy outlays of money. The railroads and public highways spend enormous sums in clearing tracks and in construction of temporary barrier fences against these sand encroachments. Much of the fighting is now being done in such a way that it must be done over and over yearly—viz: on the leeward side where the freshly blown sand falls. The work should be begun at the other side of the dune if the sand problem is to be settled. If the planting is done at the water edge, or at the edge of the break on traveling dunes, then the newly washed up accumulations are kept covered by vegetation. If the planting is always worked toward and close up to the high water, the serious damage of drifting sand may be overcome. On the southeast shore of Lake Michigan there are long stretches where sand accumulates rapidly, and there annual planting on this newly formed land must not cease, once the bare expanse of naked dunes back from the shore are covered. There will always be a cutting and filling operation carried on by the waves of the lake, but if the fills are planted close to the high water break, this problem becomes a simple one of willow planting with a periodical filling of permanent trees as the beach area is built into the lake. It cannot be hoped to prevent the building up or the cutting away of the shore lines with planting.

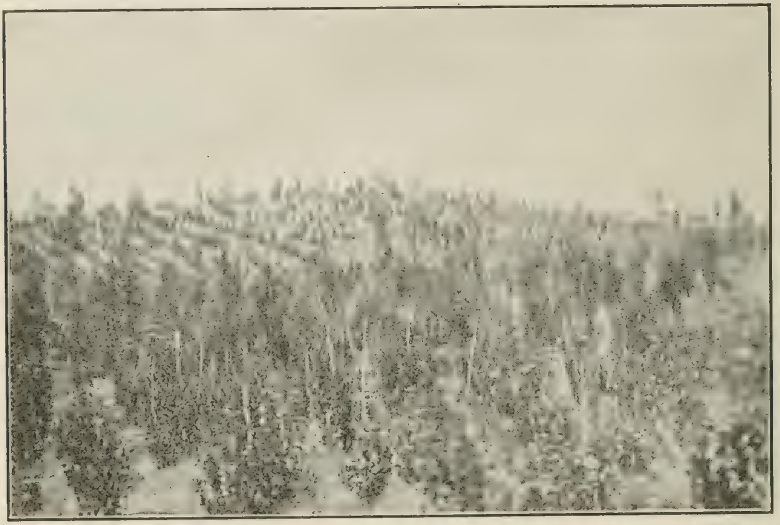

Fig. 7. Government planting on south face of Creeping Joe at Manistee two years after the temporary cover was established. Dense belt of mass planting in the foreground to hold sand and break the sweep of the wind.

DUNE HISTORY AND EARLY EFFORTS TO CONTROL SAND.

The encroachment of sand from Lake Michigan upon valuable orchard, farm, and timber land has been a matter of much concern for many years. Many theoretically correct but half hearted attempts have been made to reclaim portions to some form of control. The investigative reports of studies made by various organizations usually conclude by offering recommendations, the carrying out of which would cost many times what the land is worth. These lands are very largely privately owned which fact makes their reclamation much more difficult than where they are owned by the State or Federal Government. Experiments have been tried with entire success in many spots along the west shore. Where failure has resulted it has been due to the discontinuance of the work before a final cover of permanent forest growth became established. A very noteworthy example of the success of the efforts to bind drifting sand was found at Manistee on a dune known as Creeping Joe, a large formation formerly covering one hundred or more acres. This dune is shown in figs. 6 and 7, in 1904, about two years after the Government planting was made. Very extensive plantings of beach grass, covering the face toward the lake, were established uniformly and reached to the crown of the main dune. Where permanent planting of black locust, Carolina poplar, spruce or pine was made in groups or blocks a crust was formed by the grass and tree roots which held the sand. Where no tree planting was made and where grass was depended upon solely to form the cover, frequent breaks occurred which gradually widened until all signs of grass or other growth were totally lost. (Fig. 8.) The poplars completed the crust and windbreak, but were not suited to form a permanent cover. Blocks of black locust and spruce were used which have formed a permanent cover, and in 1914, twelve years after planting, these blocks were withstanding the wind and sand action perfectly. (Fig. 8.) On the areas where only grass was used as a cover nothing remained in 1914. Several places were found where poplars had been planted in 1902. (Fig. 9.) These were gradually being overcome by the sand but still plenty of shelter was provided by the growth present to insure establishment of a permanent forest. Such was the condition found at the crest of the once active dune twelve years after the temporary plantings of grass and poplars. At any time during the interval of this dozen years a planting of permanent forest trees could have been made with every chance of success. There were several noteworthy examples of blocks of permanent planting on the windward side of the dune as shown in Figs. 8 and 10. No permanent planting followed the grass planting, the result being that the block of locust shown in

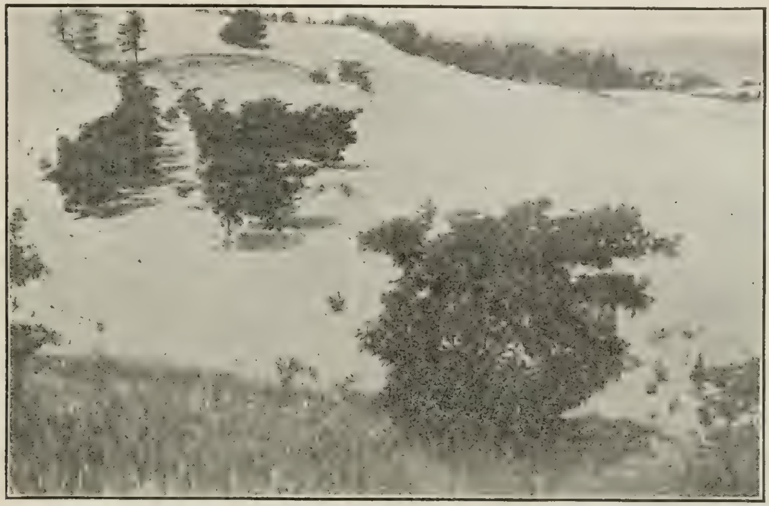

Fig. 8. Black Locust growth in a clump on the southwest slope of Creeping Joe. Government planting of 1902-3. This tree resisted successfully the burying action of the sand while spruce. larch, pine and fir were killed. Patches of marram remain in the protected spots.

Fig. 8 had no protection after the grass cover broke. Nevertheless they have maintained a healthy and normal if not rapid growth. Incidentally it should be remarked that in this locality black locust was entirely free from the locust borer in August 1914. Fig. 8 further shows remaining evidence of grass still struggling against the constant tugging of the wind.

Another splendid example furnished by the United States Government's early work is at Saugatuck. A uniform planting of grass was made, the plants being secured close by and spaced 18 by 18 inches, at a cost of approximately $45.00 per acre. Here again too much was expected of the grass and dead cover. The last and most important operation was not performed, viz, the establishment of a permanent forest. Such instances as these show the inadvisability of attempts on the part of private owners to conquer the bad dunes at one operation by the use of beach grass alone. If, however, funds are plentiful and immediate results are demanded, successful reclamation may be secured by following the entire cover system which is described later. For the small owner or the farmer of moderate means other methods must be applied, calling for moderate annual expenditures and slower results.

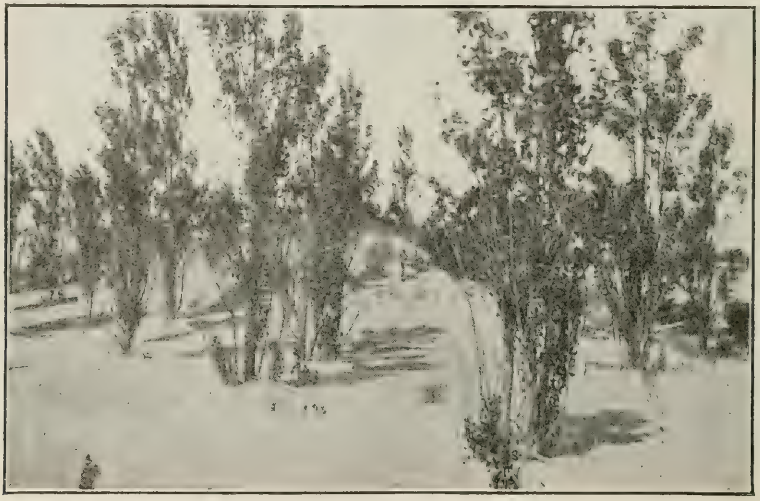

Fig. 9. Poplars half buried in a dune. Permanent planting should have been made before this temporary cover lost its grip upon the sand.

ORIGIN OF "BLOWS."

The vast ridges of sand often towering a hundred feet or more above the water and extending in almost unbroken series from the southwest corner of Michigan to the Straits, bear mute evidence of the ceaseless activity of the water-wind action. Much of the surface of this series of dunes has become forest covered, the same as other land. While there are no data available there is every indication that under the wild natural condition of things, most of the dune sand became covered with permanent vegetation. With the exploiting of the timber wealth of

Michigan, however, the virgin pine, spruce, cedar, maple and oak was removed. Following this came the fires which removed the "crust" over this sand, formed during many generations of plant life. Many of these burned over clearings were cultivated for a time until the humus accumulation and root binder material had become exhausted. Often two or three croppings were sufficient to render these sands worthless for farming purposes. Such areas are spoken of as *"blows."*

NEW DUNES.

The new dunes and blows are those along the water edge of the lakes. The disturbance is not primarily an agitation of the old sand but the constant movement of new sand which is brought up from the bottom of the lake by wave action and cast high on the shore by the breaking water. During the breaking down process the particles of rock become finely pulverized by water action and contact with each other until there is formed a smooth surfaced grain called smooth sand. All the angles and sharp edges have been worn smooth. The form becomes globular, oval or rounded. In this form it is easily tossed on the beach by the waves. It soon dries and the wind tumbles it higher up the slope until it forms a part of the mass of sand that is building the new dune, burying the orchard or covering the field. When a break in the surface of the old, formerly forest covered dune occurs as may be caused by a road or footpath, conditions are right for the development of a new dune, and the treatment is the same as for other forms of shifting sand.

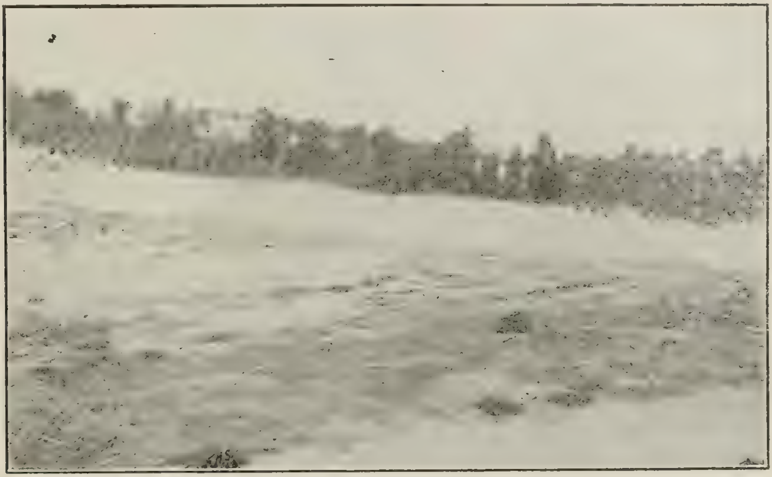

Fig. 10. A shelter belt established at Manistee by the Government. This belt was five to six rods wide and proved a success as far as it went. No follow up or later planting was done and the good effects of the belt were wasted. Without more permanent planting this belt will soon become buried.

PRINCIPLES TO BE OBSERVED IN SAND CONTROL WORK.

Sand dune control is expensive and is justifiable only where an economic necessity demands it, or where the initial expense is justified by the consideration of future production and profit from the land. Under the first case would fall such objects as the encroachment of dunes upon highways and railways, the blocking of channels and harbors, the burial of land within municipal corporation boundaries and areas valuable as city forests and parks, and the encroachment upon valuable orchards and farm land. The second class includes those farm lands which should be made to yield periodic crops of short rotation timber and also those large areas of wild land which are now held for investment or future development.

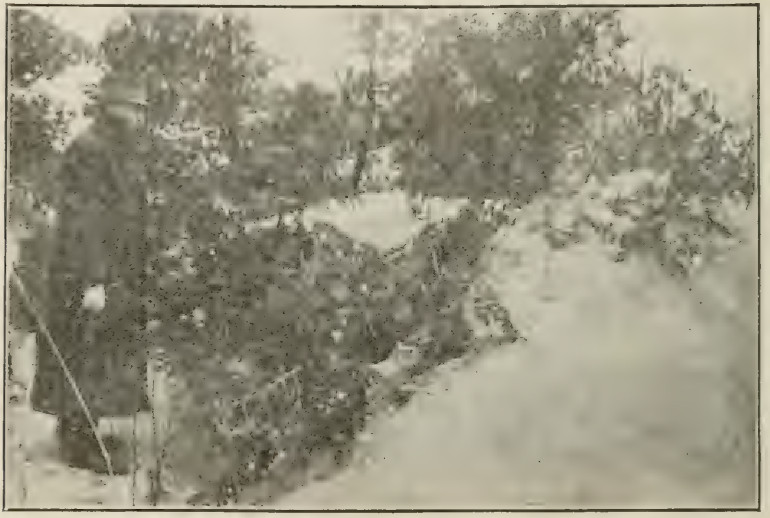

Figure 11. Destructive action of sand blow during the late winter. Sand has covered the snow to a depth of a foot or more, resulting in the burying of large numbers of smaller trees and shrubs. These results are always found on the lee edge of the drift.

In any case where sand blows occur the question of the future value of the property is in direct relation to the productive capacity of the land in the years to come. A sand blow yields nothing to the owner, and must always lie on the market as non-productive land. A sand blow planted and controlled by timber cover becomes an asset as soon as the cover is established. It at once becomes productive land and its future value increases. To what degree its selling value will increase depends upon various factors such as accessibility and desirability as resort or estate property and upon its timber value.

METHODS OF CONTROL.

Many plans of control have been worked out for the Cape Cod Dunes, the dunes along the Columbia River in Oregon, and European dunes. None of these methods can be applied to the Michigan dunes, because either the work was too costly, too intensive, or required immediate completion. The private individual can not afford heavy expense where there is no prospect of immediate returns. A system is therefore necessary which reduces the initial expense and spreads the work over a longer period. The labor problem also prevents the private owner from securing planting material at the proper season. Planting stock is hard to secure in quantities, especially beach grass. Effort to complete the reclamation in one or two years often results in careless planting or in leaving unplanted areas which soon develop bad blow conditions and ruin the earlier work. These facts have been taken into consideration in the following plan.

The fact that the new sand first makes its appearance at the water line or high water mark, establishes this as the point of first attack. The first planting that is done amounts to a border planting using any material capable of withstanding the rigors of exposure—rough seas and ice conditions are often very severe on living woody growth. On the fine sand beaches the use of beach grass, beach willows, sand pea and other local plants that are easily secured is recommended. The important principle is the establishment of a vegetative belt parallel to the water line and as near to it as plants will grow. In many places along the Lake Michigan shore grass planting is not necessary because of the firm holding condition of the surface near the water. This is due to various compositions entering into the make up of the soil, principally however to the coating of small pebbles or coarse gravel known as shingle. These conditions furnish splendid ground for the planting, the wind being the only factor working against the plants. Often it has been possible to collect drift material enough to make a wind and spray buffer between the high water line and the planting line. Logs, stumps, sticks, barrels, boxes, etc., furnish a good protection to the low growing first cover planting from the severe sweep of the winds.

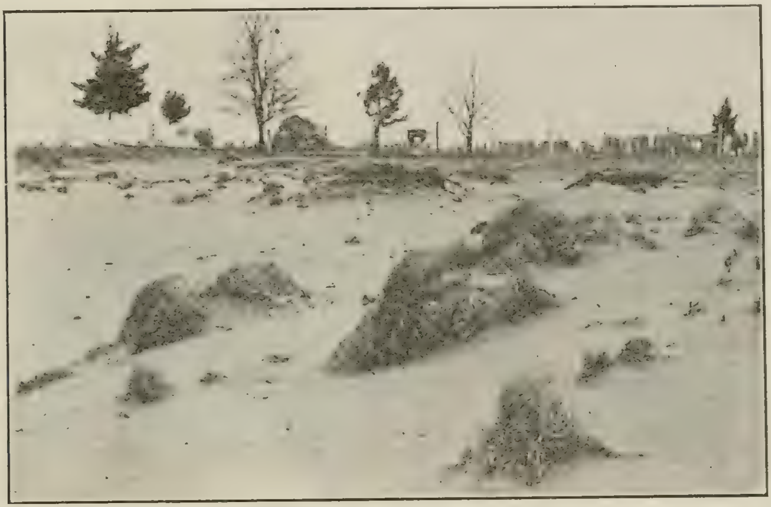

Fig. 12. Wind erosion at Big Prairie. This cemetery lay in the path of a blow. Such a condition as this might justify a heavy expenditure in the establishment of the Entire Cover System of sand control.

BARRIER OR SHELTER METHOD.

Sand blows often occur which do not warrant extensive outlay of time or money. The private owner is willing to do something, but he wants to do it gradually, a little at a time as his means and time warrant. To such conditions the Barrier Method of control is advisable. The vulnerable point of attack must first be determined. This is indicated by the general travel direction of the sand. On shore sand dune work there is only one point of beginning and this is at the water edge. With inland blows however this point may be more difficult to determine especially if one cannot watch the blow throughout the year. Often there are seasonal blows from different directions, in which case different sides of the blow should necessarily come under control simultaneously.

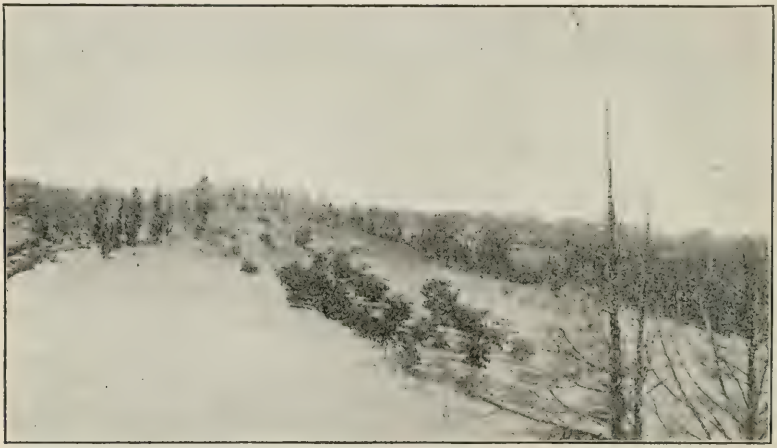

Fig 13. Birds eye view of the government planting of permanent clumps on the west slope of Creeping Joe. The haphazard location of the groups of trees furnish little or no protection to the entire cover planting on the upper slope of the dune. A few years more would have witnessed the complete burial of the temporary grass and poplar cover at the crown of the dune.

The first operation consists in establishing a living cover of sand-binding material and low woody plants with a permanent setting of small trees for both temporary and permanent shelter. For the purpose of sand-binding work, any herbaceous plant that will grow on the sand in the locality should be used. Such plants as the valuable and common beach grass (Ammophylla arenaria), the beach or sand pea (Lathyrus maritimus), Rosa virginiana, and other marsh or upland grasses and wild vetches are suitable. These are planted with 2 by 2 ft. spacing over the entire belt and later protected by the dead cover. Willow cuttings are next made from the abundant marsh willows which are common all along the Lake Michigan shore. The variety does not seem to make much difference so long as good fresh new wood from rapid growing trees is used. The cuttings should be twelve to eighteen inches long and not over three-fourths inches in diameter at the butt end. These are stuck into the sand to a depth of ten to fourteen inches so as to insure being constantly in moist sand. A row of willow cuttings is placed two feet or less apart at the edge of the belt, another row planted in the same way is set three to four feet inside of the first row. In exceptionally exposed blows it often becomes necessary to set one or even two more rows of willows, placing them closer together and thus covering the first ten feet of the belt. This forms the facing or front. Behind the willow and still within the dead cover area alternating trees of Carolina poplar, spruce or pine should be set in rows four to five feet apart. First a one-year Carolina poplar and four feet from it an evergreen, then a Carolina poplar, then an evergreen, etc. These rows, alternately poplar and conifer, are best set four by four feet on areas exposed to heavy wind. Two objects are attained in the alternate planting of poplar and conifers. First, a good growth and high per cent of living trees is assured by the use of Carolina poplar, since ninety-five per cent of the trees of this species should survive. The rapid growth for the first ten to fifteen years assures a quick shelter against the sand carrying wind. Second, the poplars are short lived and their foliage does not monopolize the entire crown area, and further, they recover readily from the wind and storm injury to which they are subjected. When the poplar has stood the brunt of ice and snow storms for a dozen or more years it should be removed to furnish space for the permanent trees. Conifers make the best permanent forest crop on exposed sands because they form a dense screen through which the wind cannot pass and cast a dense shade which is conducive to the accumulation of humus forming litter, preventing the excessive drying out of the sand floor which often occurs during the dormant season when covered by deciduous trees only. They are also quite free from insect pests and produce higher returns from the lumber than do the hardwoods. Conifers do not succeed when planted alone on the sand dunes, however, because, owing to their slower growth at the start, they are more easily blown out or buried during the early years after planting, and they present a heavy evergreen top before the roots are sufficiently established to withstand the pulling, rocking action of the wind, which loosens them to such an extent that they are barely able to keep alive. They also suffer during the first and second seasons from excessive transpiration when standing unprotected.

An artificial or "dead" cover should be established in bad cases. This consists of any convenient material being placed on the land at the point of wind attack. (Fig. 6.) Cornstalks, rotted marsh hay, brush, poles, old lumber scrap, rotted saw dust, cut weeds, etc., may be used, or sometimes short stakes, barrel staves, etc., may be driven into the sand at close intervals. The sole object of this cover is the obstacle furnished to the clear action of the wind. This material should be placed uniformly over the belt or strip extending along the edge of the blow or along the shore of the lake, and a few feet above the high water mark of winter storms and ice. The width covered depends entirely upon the size of the dune and the resources available in any one year for the work. The belt may be covered for a width not less than a rod and preferably at least three or more rods the first year. The covering of this belt with dead material constitutes the last operation and is known as the dead cover.

Subsequent work under this method should be carried on by the establishment of successive belts parallel to the first. An interval of one hundred feet or more may be left between the first and the second belt. The second belt is established in the same manner as described above, except that one or two rows of willows will ordinarily be sufficient to form the facing. From the later belts all willows may be omitted, using poplar and evergreens exclusively. When the second belt is being established the dead cover should be used if there is evidence of much sand travel over the surface. Under this method a belt is established each year, each succeeding belt approaching nearer and nearer the top of the dune. If the elevation increases rapidly the space between the second and third, and third and fourth belts should be narrowed to seventy-five and fifty feet, respectively. When four or five belts have thus been established, enough shelter should have been provided for the open strips between belts numbers one and two and between numbers two and three, so that these may be sown to rye and grass, sweet clover, or any perennial capable of making some growth in this kind of soil. In many cases where severe blows are cutting away old dunes, as well as carrying fresh sand from the water, it will require many years of annual work to reclaim the land. The flat or more level portions between the water and the top of the dune must first be covered with forest growth, thus cutting off the supply of fresh sand, and breaking the sweep of the wind. As the higher portion of the blow is reached, where cutting away of the old dune is going on, recourse will again be necessary to the use of willows and poplars which must be underlaid thoroughly with dead cover. The windward edges of these cuts must always be the first ones treated. Once the shelter belts are carried and established to the top of the dune, a return is made to the grass covered areas between the breaks or barriers. Here good forest trees of many varieties may be planted. Choice of species depends entirely upon the object of the owner

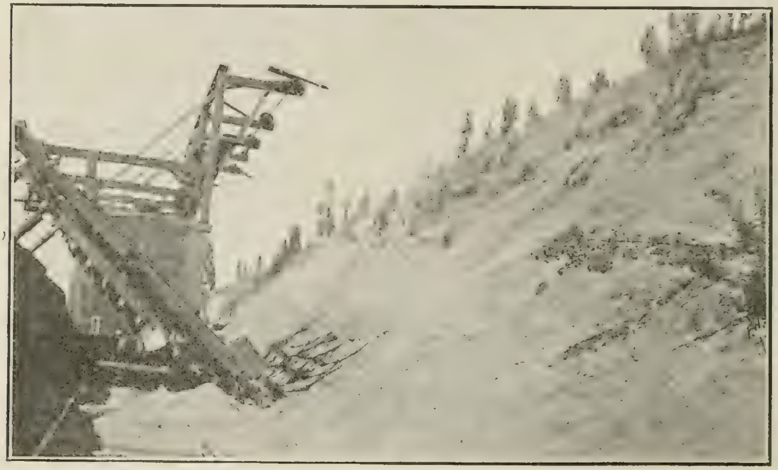

Fig. 14. The Railroad Company loaded this dune upon cars and carried it across the State to be used in sand blasts.

The results of the temporary cover planting by the Government on this dune were excellent. The chief fault was that no permanent trees were planted later.

The mass sliding down the bank is the poplar and herbaceous material which formed the crust. Roots were measured on both Carolina poplar and black locust which reached down into the sand for one hundred feet.

and possible future utilization. In many places nut trees can be handled to advantage where heavier soils are found underlying the sand. In some blows, orchards might be maintained on the strips between the barriers, It seldom is advisable to use annual crops upon these strips. Once established a tree canopy should always exist. When a break occurs through the opening of a gap in a barrier, for road or street, the soil exposed should be paved or sodded to prevent excavation by the wind. The later management of the forest must be by a conservative selection removal of individual trees and never by clear cutting.

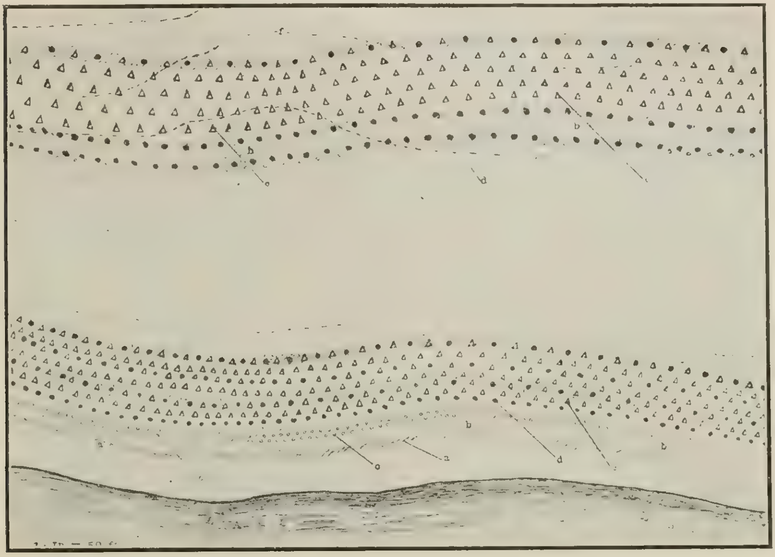

Fig. 15. Diagram of Shelter Belt Method.
a. Barrier of rubbish and waste.
b. Beach grass planting.
c. Willow cuttings.
d. Poplar cuttings, or rooted sets.
e. Conifer planting.
f. Contour lines.

ENTIRE COVER METHOD.

This system of dune reclamation is applicable either where immediate cover is required, where future values justify the expense of immediate and heavy planting, or where sufficient funds are available for the completion of the work. In some cases extensive areas of valuable property are in the immediate path of a rapidly traveling dune. Fig. 12 shows a cemetery lying in the path of an interior blow, reclamation of which might justify the expenditure of large sums for quick control. On smaller dunes this method is especially applicable, as where a city or town may be the unit doing the control work. Municipal organizations are usually in a position to purchase such areas if they are held by private parties who refuse to control them. Such steps seem advisable, since, when once under control these areas become valuable park or municipal forests. The planting of such areas would best be done by the Entire Cover System since results are desired quickly. Another class of ownership which would use this system of reclamation is the investor in summer resort properties. Holdings of sand dune blows and barrens are made especially attractive as sites for summer colonies when covered with forest. Thousands of acres of shifting sand along the shore of Lake Michigan may be eventually converted into summer home sites, by the expenditure of money in systematic cover planting for sand control.

The Entire Cover Method is a complete covering of the sand in a single season. For convenience in carrying on the work it is best handled in three operations, first, grass planting; second, willow belt planting, and dead cover. The labor under this system is divided into three squads or crews numbered for convenience A, B and C. Squad A should be assigned to grass planting work entirely. Considerable skill in setting the plants is soon acquired. The size of the crews will vary with the lateness of the season. Ordinarily ten men make a good planting unit for one foreman to handle. Squads B and C with their foremen are assigned to the collection of grass plants. If the distance is not too great, say a mile or two between the planting site and the source of material, the two squads will secure, transport, and "heel in" plants enough during the first week to keep squad A planting steadily for about three weeks. Beginning with the second week, squad B is assigned to planting the willow cuttings in belts as shown in Fig. 15. At this time squad C begins the collection and hauling of dead cover material which may be piled up at convenient points near the planting. Then squad C begins the planting of the poplar and conifer stock about ten days after squad A began. The trees are planted in rows five feet apart, unless the blow is very severe, then a four foot spacing is preferable, alter-

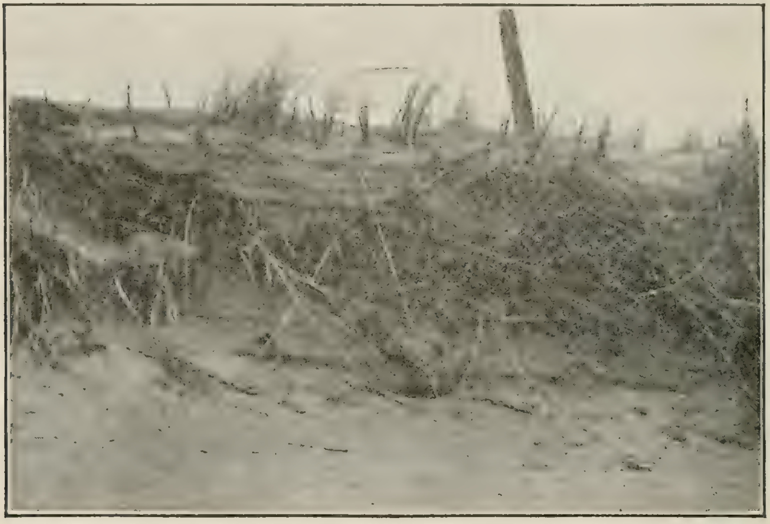

Fig. 16. The valuable work of beach grass. This mound of sand was very securely tied down by the roots of this grass. No other plant could possibly gain a footing so rapidly nor resist the wind action so effectively.

nating Carolina poplar with conifers. The conifers should be so set that they stagger in the succeeding rows in order to furnish greater obstruction to the wind. Toward the last of the planting a few men may be taken from squad B to distribute and spread the dead cover.

Except on very severe blows the dead cover need not be spread uniformly over the whole area, but applied in strips at right angles to the direction of the prevailing wind. These strips may be from ten to twenty feet wide with intervals between of twice this width. Usually about one-third of the area should be covered. Where both fine and coarse materials are available, the coatings alternate with coarse, fine, coarse, fine, etc. Grass, marsh hay, straw and other light materials that are liable to be moved by the wind may be held in place by brush. Where well rotted sawdust is available it may be used alternately with strips of grass or straw and brush. Sawdust cannot be used alone as it dries out and blows readily. In some cases, when the season is damp and there is plenty of moisture at the surface, a broad-cast sowing of rye or oats may serve to help bind the dead cover and protect the planted grass. The success of this expedient will depend entirely upon frequent rains to insure the germination of the rye, however.

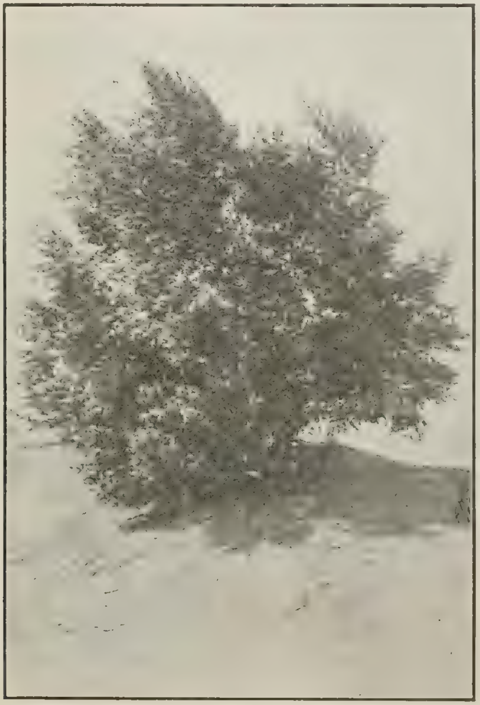

Fig. 17. A paper birch alone and unprotected on the face of a dune. This tree stands on a mound of sand eight feet high and twenty feet across. The roots held the mound while the sand around the mound was swept away. A valuable tree to encourage because of the sand holding power of its root system.

CONCLUSIONS.

There are two general plans of operation in the work of sand control. The Shelter Belt or Barrier System is suitable to private owners. It may be so managed as to enable the man of limited means to systematically do a portion of the work each year until the whole blow area is under permanent forest cover. The Entire Cover system calls for heavy expenditure in labor and materials but has as its aim the completion of the work over the whole area in a single season.

In this system the need of a provision for follow up or repair work must be made.

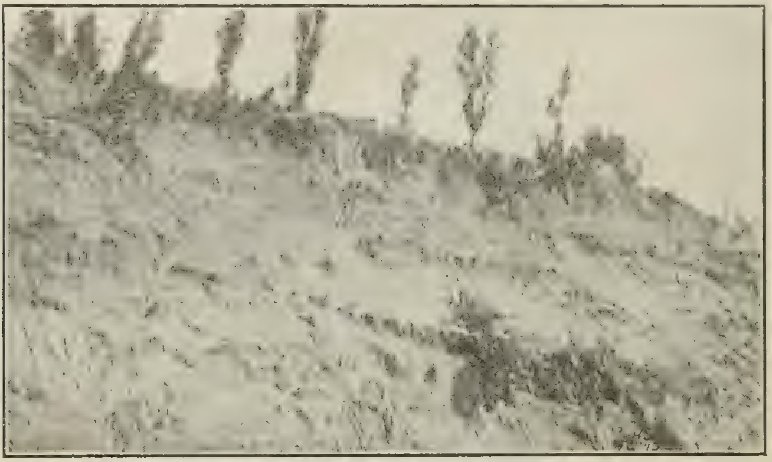

Fig. 18. The crust of this dune was formed by marram and other herbaceous growth. The poplar and locust roots completely penetrated the body of the dune. Notice the very persistent crust at the top of the dune. The temporary cover was a success in completely holding the sand.

Sand along the Michigan shores can be controlled if proper methods are applied. Certain plants are admirably adapted for use in establishing a "crust" in which other forms of tree growth must be planted to insure permanent forest cover.

By waiting for planted belts to grow into high shelters, certain adjacent belts in the lee may be utilized by the growth of certain forest crops, or orchards, but never by annual crops.

Studies of planting done from ten to twenty years ago point out the imperative need of establishing and maintaining a solid cover on the windward slopes of all blows.

Planting must begin on the windward side of a blow with the establishment of a facing of low forms that are capable of withstanding the rough treatment to which they will be subjected.

In all dune formations where the sand is cast up by water a control shelter of hardy shrubs must be set as close as possible to the winter line of high water and ice. An artificial barrier of drift material and wood forms a splendid protection and justifies considerable expense to establish it.

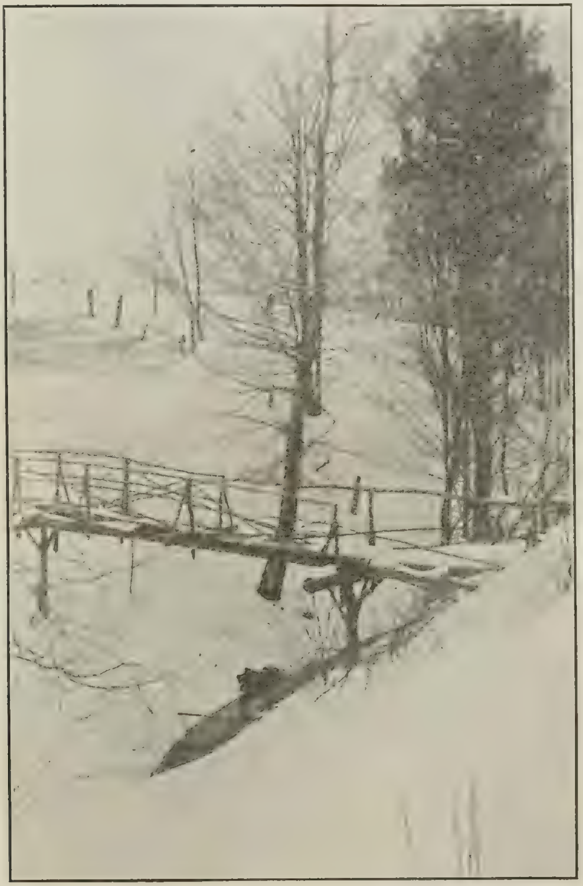

Fig. 19. A break in the surface of an established and wooded dune due to construction of a trail. This started the sand to traveling through the timber until it filled a ravine and buried a foot bridge. A bad traveling dune was soon formed.

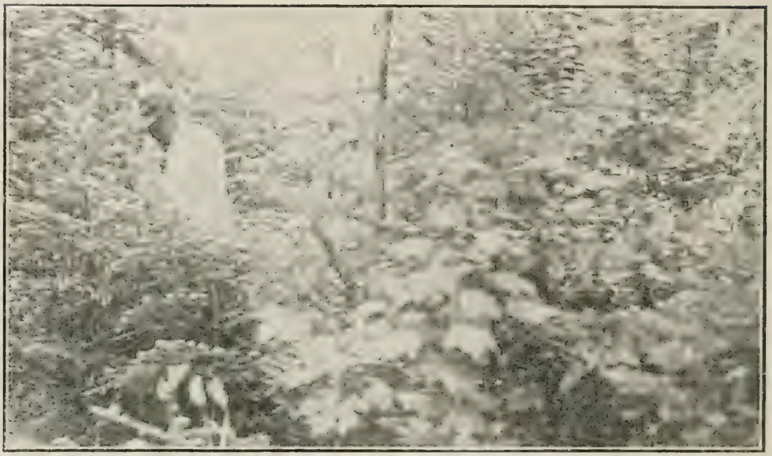

Fig. 20. A dense mass of mixed hardwood and conifer growth of fifteen years at Frankfort on the dune property of H. A. Lewis. Such a cover becomes a splendid insurance against sand blow damage and materially increases the value of the land.

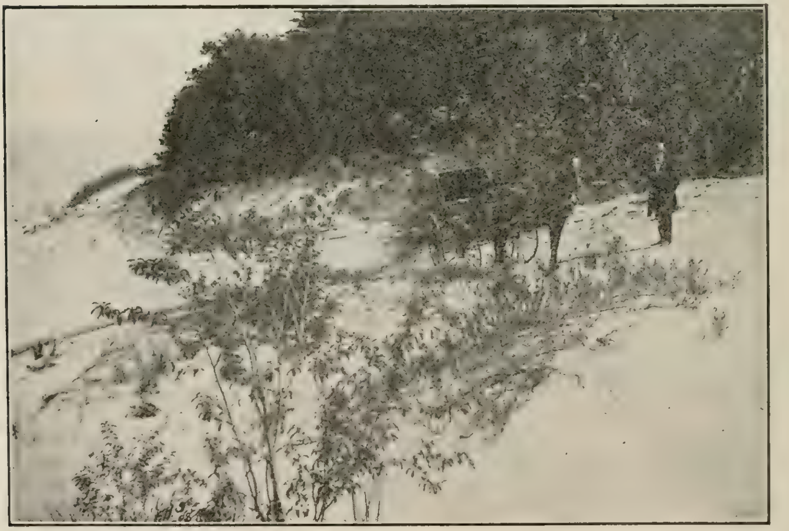

Fig. 21. In many places the beach presents a half naked condition varying in width from ten to eighty rods between the high water mark and the foot of the established dune. There is plenty of space on such areas for the planting of heavy foliaged conifers which will strengthen the protective cover of the dune and produce valuable timber.

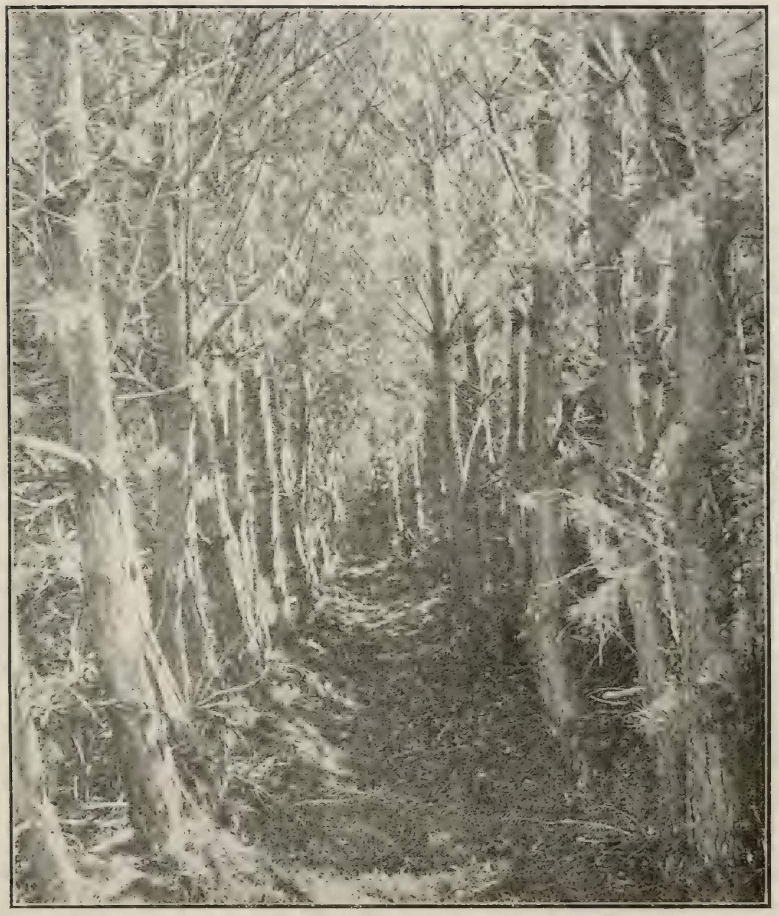

Fig. 22. A fine growth of Scotch pine at Pier Cove, Michigan. This pine is not generally as desirable for sand planting as either White or Norway. It is brittle and when loaded with ice or snow suffers heavily from breakage. It grows quickly on light sands however, and is a fairly good tree for sand work.

EXPERIMENTS ON THE CONTROL OF THE ROOT-KNOT NEMATODE.*

Technical Bulletin No. 20.

BY J. A. MC CLINTOCK,

Agent B. P. I. in charge of Ginseng disease Investigation of Michigan.

The root-knot nematode, *Heterodera radicicola,* (Greef) Müller, has proven to be a serious pest of many crops in the southern states, and in some of the western states it has caused considerable trouble on potatoes and sugar beets. In many of the northern states, this nematode has caused serious trouble on greenhouse crops and on such intensive garden crops as ginseng.

The life history of this parasite has been worked upon by (1) Atkinson†, (6) Stone & Smith, (2) Bessey, (3 and 4) Cobb, and control measures have been worked out for greenhouse conditions by Stone & Smith; while Bessey and (5) Rolfs have recommended rotations that tend to keep the root-knot nematode more or less under control in certain field crops. Much still remained to be worked out in the way of control measures for intensive crops like truck crops, ginseng, golden seal, etc.

For an account of the complete life history of the root-knot nematode see Bessey (2). Briefly it is as follows:

In about twenty-five days after the female enters a root, she has reached sexual maturity and begun to lay eggs. These eggs which are 85-98 microns in length by 34-40 microns in thickness, are surrounded, as laid, by a gelatinous substance which holds them together in a mass. In the case of firm, woody tissues, the eggs seldom reach the surface of the knot, but produce numerous larvæ which make their way to the surface and enter new roots. Where the root-knot is in softer tissues, as those of various herbaceous plants, the eggs are often forced through the tissues and cling in small masses to the surface of the knot. The number of eggs laid by a single female varies somewhat, but counts seem to show that it is between four and five hundred. In all cases where the number of eggs used in experiments is recorded, it is on the basis of four hundred eggs per egg mass, so in most cases the number of eggs treated probably ran over rather than under the number recorded. Under favorable conditions, the eggs probably begin to hatch within a few days after being laid, thus making the complete life cycle about thirty days under favorable conditions.

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*The work upon which this paper is based was carried on under a cooperative agreement between the Bureau of Plant Industry and the Michigan Experiment Station, and in somewhat different form was accepted as a thesis for the degree of Master of Science in the Department of Plant Pathology, University of Wisconsin.

†The number with the author's name refers to the number of the article referred to as listed in the bibliography at the close of this paper.

FIELD EXPERIMENTS CONDUCTED IN MICHIGAN IN 1915.

As the chief work assigned to the author in Michigan was that of experiments on the control of the root-knot disease of ginseng, it was necessary to make a general survey of the various ginseng growing sections of the state, in order to select a suitable place for establishing a field laboratory. It was finally decided that a large garden located at Muskegon, Michigan, afforded the best opportunity for carrying on field experiments so the field laboratory was located there.

In order to exclude, as far as possible, any factors which might lead to errors in the results, it was decided that the plots used for experiments should be separated from the remaining soil. To accomplish this the plots of soil, seven by ten feet in extent, were enclosed with galvanized sheet iron thirty-six inches in width. The iron was set into the soil thirty inches, leaving six inches projecting above the surface to keep any surface soil from being washed into the plots after the experiments were started. The observation of nematodes three feet down in the soil has been recorded by Bessey (2) but the difficulty of obtaining iron more than thirty-six inches wide was so great as to preclude our placing it more than thirty inches in the soil. The edges, where the sheets of iron came together, were bent, interlocked and pounded tightly together to prevent the passage of anything at such places. To exclude the possibility of soil being carried onto the plots, by various animals passing through the garden, each plot was enclosed above ground with a three foot fense of chicken-wire netting, which came down so as to overlap the six inches of sheet iron above ground.

The plots, seven in number, were alternated with two foot paths, so as to cover the greater part of a strip of soil fourteen feet wide and seventy feet long. Two beds of badly nematode infested ginseng roots had been removed from this soil the fall previous, and no crop had been on the ground since. The soil, throughout the whole garden, is a loose, sandy loam, very highly fertilized with barnyard manure, making it an ideal place for the rapid multiplication and spread of the root-knot nematode.

Although the experiments of previous workers with chemical treatments of the soil for the eradication of *Heterodera radicicola* had given chiefly negative results, it was decided that a series of such treatments should be made to test the relative value of various chemicals, with the possibility of finding one that would be both effective and practical of application.

CARBON BISULPHIDE TREATMENT.

As previous experiments by Bessey (2) had shown carbon bisulphide to be successful under field conditions, it was decided that one plot should be treated with this chemical exactly as recommended. On the afternoon of May 10, 1913, plot I was treated with carbon bisulphide as follows:—Holes were made in the soil at intervals of six to twelve inches, and varying in depth from six to eighteen inches. Liquid carbon bisulphide was poured into the holes at the rate of four ounces per square yard of soil, and the holes quickly plugged up by packing soil into them. Within half an hour after the treatment was made the air, in the vicinity of the plot, had a very strong odor of carbon bisulphide, and the odor was still quite noticeable the next morning after the treatment. From this it was concluded that the vapor had been passing up through the soil and out into the air for a period of about eighteen hours. Lettuce, tomato and cucumber plants are among those most readily attacked by the root-knot nematode; therefore, it was decided to use these plants to determine whether or not the soil treatments had eradicated the pest. May 14, 1913, lettuce seeds were planted in the carbon bisulphide treated plot, and also in the untreated soil about the plot to serve as a check on the treatment. May 31, 1913, the seeds planted May 14th had not produced many plants so the plot was replanted with lettuce, tomato and cucumber seeds. June 16, 1913, some of the larger lettuce plants were dug from the plot and their roots found to be somewhat affected with nematodes as shown by the small knots on them. Check plants dug from the soil outside of the plot were more seriously affected than those from the treated plot, thus showing that the nematodes had been reduced in numbers, but not eradicated by this carbon bisulphide treatment.

June 30, 1913, the rest of the plants were dug from the treated soil and the roots were found to be abundantly covered with knots, showing that the nematodes were increasing in numbers in the treated soil. August 16, 1913, this plot was retreated with carbon bisulphide as before, except that the surface of the soil was sprinkled with water and covered with burlap sacks, after the treatment, in an effort to keep the carbon bisulphide vapor from passing so rapidly from the soil out into the air. August 18th the sacks were removed from the surface of the plot and lettuce seed was planted in the treated soil. September 8th some of the lettuce plants were dug and examined but no knots were found on the roots. It was impossible to get further data on this plot during the rest of the season. In the summer of 1914 the author examined lettuce and cow pea plants from this plot and found nematodes on their roots.

TOBACCO STEM TREATMENT.

The second plot was treated with tobacco stems. A wagon load of tobacco stems was collected from various cigar factories and taken to the garden. May 12, 1913, a layer of these stems over six inches in thickness was spread over all the soil of plot II. May 14, 1913, the stems were wet down with water. May 31, 1913, the layer of tobacco stems was removed from the plot and lettuce, tomato and cucumber seeds were planted in the treated soil, and also in the untreated soil outside the plot. June 16th some of the plants were dug from the treated soil and examined but no knots were found on the roots. June 30th lettuce, tomato and cucumber plants were dug from the treated soil and examined but no knots were found on their roots. August 11th, the author dug up lettuce, tomato and cucumber plants from the treated soil and found some small knots on their roots, showing that the nematodes had been reduced in numbers for a time, but not eradicated. The writer does not feel that such a treatment can be depended upon to give the desired results.

SULPHURIC ACID TREATMENT.

August 14, 1913, all of the remaining plants were dug from the second plot. The soil was then treated with a solution of one part of commercial sulphuric acid to eighty-five parts of water, using one-half gallon of this solution per square foot of soil. August 18th lettuce seed was planted in the treated soil. September 8th lettuce plants were dug from the plot and examined, but no knots were found on the roots. It was not possible to get further data on this plot during the rest of the season, but in the light of experiments performed later in the laboratory at the University of Wisconsin, it is probable that the sulphuric acid treatment did not eradicate the nematodes from the treated soil. In the summer of 1914 the writer examined plants from this plot and found root-knots on them.

FORMALDEHYDE TREATMENTS.

It was decided that the third plot should be treated with formaldehyde. In 1912 some preliminary experiments along this line were started. During April, 1913, we had an opportunity of seeing the results of these soil treatments with a solution of one part of 40% formaldehyde to fifty parts of water. These treatments had not been successful in eradicating the nematodes from the treated soil; so we decided to double the strength by using 1-25 formaldehyde (1 part of 40% formaldehyde to 25 parts of water). May 12, 1913, plot III was treated with a 1-25 solution of formaldehyde, using one gallon to a square foot of soil. May 14th lettuce and cucumber seeds were planted in the treated soil to see if they would germinate and grow before the soil was free from formaldehyde gas. May 31st no lettuce or cucumber plants had come up from the seeds planted May 14th, so the plot was planted with lettuce, cucumber and tomato seeds. June 16, 1913, some of the plants were dug and examined, but no knots were found on the roots. June 30th, the author examined lettuce, tomato and cucumbers plants, but found no knots on their roots. August 11th, he dug up and examined lettuce, tomato and cucumber plants and found some small knots on their roots. This showed that the treatment with 1-25 formaldehyde had greatly reduced, for a time, the number of nematodes in the soil, but had not eradicated them.

August 13, 1913, the writer dug up all of the remaining plants from Plot III, respaded the soil, and then raked it so as to note and remove as far as possible, any pieces of roots which had been broken from the plants in digging. The soil was then retreated with a formaldehyde solution made up at the rate of one gallon of 40% formaldehyde to sixteen gallons of water, and applied at the rate of about one gallon of solution to a square foot of soil. August 14, 1913, lettuce seed was planted on this plot to see if it would grow before the formaldehyde gas was out of the soil. September 3, 1913, no lettuce plants had developed from the seed planted August 14th; so the plot was replanted with lettuce seed. September 8, 1913, no plants were up. No further data could be taken on this treatment during the rest of the season; therefore, we came to no definite conclusion relative to the value of this treatment. During the summer of 1914 plants from this plot were examined and nematodes found in the roots.

NAPHTHALINE TREATMENT.

As naphthaline was known to be more or less of a repellant to certain insects, it was suggested that it be given a trial. The original intention was to mix flake naphthaline with the soil. As it was not possible to obtain naphthaline in the flake form at the time it was desired to start the experiment, it was necessary to use it in the form of small balls, commonly called "moth balls." May 15, 1913, plot IV was treated as follows:—Holes were made in the soil at intervals of eight inches to one foot, and varying from six to twelve inches in depth. One or two naphthaline balls were dropped into each hole and the mouths of the holes then closed with soil packed into them. About one and one-half pounds of moth balls were used on the plot. May 31, 1913, the writer planted tomato and cucumber seeds in the naphthaline treated soil. June 16, 1913, some of the plants were dug and examined and found free from root-knots. June 30, 1913, the author examined tomato and cucumber plants from plot IV and found knots on their roots. This proved that the naphthaline treatment applied would not control the root-knot nematode.

AMMONIA TREATMENT.

May 15, 1913, plot V was prepared for treatment as in plot IV, by making holes in the soil with a brass dibble. A small amount of 28% ammonia was poured into each hole, and then the holes were quickly plugged with soil. The ammonia gas soon penetrated the soil and gave the air in the vicinity of the plot a very strong odor. About three pounds of ammonia were used on this seven by ten foot plot. May 31, 1913, lettuce, tomato, and cucumber seeds were planted in the treated soil. June 16, 1913, some of the plants were dug up and knots found on their roots. This would seem to show that such an ammonia treatment had no effect on the nematodes in the treated soil. Later on in the season this plot was used for starting an experiment with ginseng roots apparently resistant to nematodes.

"BLACK LEAF 40" TREATMENT.

It had been intended to make this and the following treatment at the same time the others were made, but they were delayed because we could not get the "Black Leaf 40" and the tobacco dust at that time. "Black Leaf 40," a commercial nicotine product made by the Kentucky Tobacco Products Company, has proven quite efficient as an insecticide for certain types of insects. As a result of its success as an insecticide, it was suggested for nematodes. Directions on the sealed can recommended the use of a one-half pound can of this concentrated nicotine product to thirty-four gallons of water, for all ordinary insects. This dilution was supposed to give not less than seven hundredths of one per cent nicotine. May 31, 1913, plot VI was treated with "Black Leaf 40" solution made up according to directions, and applied to the soil at the rate of one gallon per square foot. June 2, 1913, the writer planted lettuce, tomato and cucumber seeds in the treated soil. June 30, 1913, he dug up and examined lettuce and tomato plants from plot VI and found knots on their roots, thus showing that such a dilution of "Black Leaf 40" would not control root-knot nematodes.

TOBACCO DUST TREATMENT.

Tobacco dust, made by grinding tobacco stems into a fine powder, has proven quite efficient as an insecticide; so it was determined that it should be given a trial. June 2, 1913, twenty-five pounds of tobacco dust were spread over the surface of the soil in plot VII, and thoroughly raked into the soil. The plot was then thoroughly soaked with water. Later on in the day, lettuce and tomato seeds were planted in this plot. June 30, 1913, the author dug up and examined some of the plants from plot VII and found a few small knots on their roots. August 11, 1913, he examined plants from plot VII and found knots on their roots. This would seem to show that such an application of tobacco dust as was used, would not eradicate this nematode.

KEROSENE TREATMENT.

August 11, 1913, all the plants from plot VI were dug up and the soil then treated with commercial kerosene, using ten gallons on the seven by ten foot plot. August 14, 1913,lettuce seed was planted in this plot. September 3, 1913, no plants had come up from the seed planted August 14th, so the plot was replanted with lettuce. September 8, 1913, no plants were up in this plot. No further data could be obtained on this treatment during the fall, so no conclusions could be drawn at that time. Plants from this plot were examined during the summer of 1914 and root-knots were found on them.

GASOLINE TREATMENT.

August 11, 1913, the writer dug up and removed the rest of the plants from plot VII. The plot was then divided by setting a sheet of galvanized iron thirty-six inches wide, into the soil eighteen inches. This gave two plots five by seven feet in area. One of the plots was treated with commercial gasoline, by sprinkling one gallon over the surface of the soil. The other plot was treated in a similar manner except that three gallons of gasoline were used instead of one. August 14, 1913, lettuce seed was planted in both plots. September 8, 1913, the writer dug up and examined lettuce plants from both of the gasoline treated plots and found many knots on their roots. The heavy gasoline treatment appeared to have no advantage over the light treatment, and neither seemed to inhibit the development of the nematodes seriously.

SUMMARY OF THE RESULTS OF THE FIELD TREATMENTS.

In all of the foregoing experiments the knots found on the roots of plants grown in the treated soils, were examined and dissected under a microscope to make sure of their true cause. In each case where complete data were obtainable they pointed to the conclusion that the treatment used could not be depended upon to eradicate the root-knot nematodes from the treated soil. In some cases the treatment succeeded in materially reducing the number of nematodes present in the soil, as shown by the longer periods that the plants grew in some plots before showing any knots on the roots. Treatments such as carbon bisulphide. tobacco stems or strong formaldehyde solution, which greatly reduce the number of nematodes in the soil for a month or so, might be of practical value in the case of some rapidly growing crop, which could be matured and removed before the nematodes again became numerous enough to materially injure the plants. In the case of a slow growing crop like ginseng, which remains in the soil from four to six years, any treatment which falls short of complete eradication is worthless, because a few nematodes left in the soil would completely restock it with their kind. In the course of a year or two they would be as serious as they were before the treatment was applied. In the light of these experiments, no chemical used could be recommended for the control of root-knot nematodes; furthermore, no exact explanation could be given as to just why the treatments did not eradicate the pest.

THEORIES AS TO THE FAILURE OF THE FIELD TREATMENTS.

Various theories to explain the failure of the treatments were formulated, but none of them were backed by experimental data. It was thought possible that occasional nematodes more resistant than the average, were able to withstand the adverse conditions and that these resistant ones in time succeeded in restocking the soil, when conditions again became favorable for their growth and reproduction. A second theory was that nematodes deep down in the soil, where the treatments exerted little or no influence, came up and repopulated the treated soil after the effects of the treatments had sufficiently diminished. Another possibility was that the nematode eggs in the soil were of such a nature that they were able to resist the adverse conditions and remain dormant until favorable conditions allowed the young to come out into suitable environment for their development. As the second of the above theories did not appear to be of a nature to lend itself readily to investigation in the laboratory, it was decided to turn attention to the other two in an effort to determine what relation they might have to the failure of the soil treatments.

LABORATORY EXPERIMENTS AT MADISON, WISCONSIN.

Early in October 1913, the experiments at the field laboratory were closed for the season, and laboratory work on various phases of the subject was begun in the greenhouses and laboratories of the Department of Plant Pathology of the University of Wisconsin. For some little time after arriving at Wisconsin, efforts were confined to fitting up experiments in the greenhouses, and to getting susceptible plants started so that there might be an abundant supply of nematodes to draw from for laboratory work. Considerable time was spent in various forms of laboratory experiments before suitable technique was worked out. An effort was made to get larvae free from the plant tissues by externally sterilizing knots from lettuce roots, and then placing them on plates of sterile agar. In no case did the writer succeed in obtaining any larvae free from the knots in this way. Failing in the above method, attempts were made to get the larvae by dissecting quantities of root-knots from lettuce and other plants. It was impossible in this way to get the larvae in sufficient numbers for the treatments it was desired to make.

Next was tried removing the roundish, pearly white female nematodes from small knots on the roots of various plants. It was thought that these females might produce eggs and larvae after being transferred to plates of agar. In most cases these females were not mature. When transferred to the plates of agar, they were soon overrun with colonies of bacteria and fungi, so that their development could not be followed. To avoid this contamination, it was tried treating the female nematodes as taken from the roots in various chemicals before transferring them to the plates of agar. Although in some cases they remained free from contamination after being transferred, in no case was success attained in getting larvæ in this way. Either their removal from the roots or the subsequent chemical treatments stopped the development of the female nematodes so that they never produced mature eggs.

The next effort was to obtain larvae by dissecting out mature or egg-laying females and egg masses from the older knots on the roots of various plants. Along with these females and egg masses were always some larvae that had hatched out within the knots from the first eggs laid by the females. Quantities of the egg masses from the root-knots were treated with various strengths of chemicals and then transferred to plates of agar. It was observed that the active larvae associated with the egg masses soon died when placed with the egg masses in the chemicals for external disinfection. This observation caused the writer to doubt the importance of our first theory; viz. that occasional larvae resisted the chemical treatments applied to the soil. The more observations that were made along this line, noting the apparent ease with which the larvae succumbed to weak chemicals, the more the writer was forced to the conclusion that the above mentioned theory was probably not the important factor in the failure of the strong chemical, soil treatments.

Other observations made about this time appeared to give more support to the theory that the mature eggs were the resistant stage. It was noted that in a few days after disinfecting mature females and egg masses, active larvae began to appear on the agar plates. As it was quite certain that no larvae had gone through the treatments alive, it was concluded that those found on the plates were larvae that had hatched from treated eggs. As a result of these observations, it was decided to discontinue for the time being, the efforts to determine the relative resistance of nematodes in the larval state, and to take up the egg resistance theory.

The first experiment which gave a possible explanation for the failure of the field experiments was begun December 23, 1913. A large quantity of mature female nematodes and egg masses was dissected from large knots on Primula roots and divided into seven lots of about an equal number of eggs. After being treated with the chemicals, the different lots were transferred to plates of sugar beet agar.

1. Placed the first lot in a solution made of one part of "Black Leaf 40" to 272 parts of water. This gave the same dilution as used in the field experiments.
2. Placed the second lot in full strength "Black Leaf 40" for a few minutes.
3. Placed the third lot in 1-1000 $HgCl_2$ for a few minutes.
4. Placed the fourth lot in 1-100 commercial 40% formaldehyde for a few minutes.
5. Placed the fifth lot in 1-10 solution of 40% formaldehyde for a few minutes.

6. Placed the sixth lot in pure liquid carbon bisulphide for a few minutes.

7. Exposed the seventh lot to carbon bisulphide vapor, over the mouth of a bottle of liquid carbon bisulphide, until all the active larvae were killed. All of these treatments were made between 3:00 and 5:00 P. M., December 23, 1913. The results of the treatments are given in table I.

TABLE I.—ACTIVE LARVAE OBSERVED.

Treatment made Dec. 23, 1913.	Dec. 24.	Dec. 25.	Dec. 26.	Dec. 27.	Dec. 28.	Dec. 31.
1. "Black Leaf 40" 1-272	Twenty	Abundant	Abundant	Abundant	Abundant	Active
2. "Black Leaf 40" full strength	None	Four	One	Two	Active	Active
3. $HgCl_2$ 1-1000	None	None	None	None	None	None
4. Formaldehyde 1-100	None	None	None	None	None	None
5. Formaldehyde 1-10	None	None	None	None	None	None
6. Carbon bisulph. liquid	Three	One	None	One	Active	Active
7. Carbon bisulph. vapor	None	One	Two	Two	Active	Active

January 2, 1914, the plates used above were all cleaned up. As the only means of detecting the presence of active larvae on the plates was by examining them under a microscope, it proved to be a rather difficult thing to locate all of the larvae after they had crawled away from the egg masses. Although the results of this experiment were not entirely conclusive either for or against the theory, it was decided to continue the work for the purpose of collecting data before coming to any definite conclusion.

EXPERIMENT II.—FORMALDEHYDE 1–100.

January 7, 1914, the writer dissected out about thirty egg masses from knots on Primula roots, and placed them in 1-100 solution of 40% formaldehyde for one and one-half hours, and then transferred them while still wet to a plate of potato agar. The results of this treatment are given in Table II.

TABLE II.—ACTIVE LARVAE OBSERVED.

Treatment Jan. 7, 1914.	Jan. 8.	Jan. 9.	Jan. 10.	Jan. 12.	Jan. 14.	Jan. 19.	Jan. 23.
Formaldehyde 1-100	None	None	One	Four	Active	Quiet	Quiet

EXPERIMENT III.—FORMALDEHYDE 1–100 AND 1–10.

January 24, 1914, a large number of egg masses were dissected out and divided into two lots. Placed the first lot in 1-100 soltuion of 40% formaldehyde for ten minutes and then transferred it, while still wet, to a plate of potato agar. Placed the second lot in 1-10 solution of 40% formaldehyde for ten minutes and then, while still wet, transferred it to a plate of potato agar. The results of this experiment are given in Table III.

TABLE III.—ACTIVE LARVAE OBSERVED.

Treatment Jan. 24, 1914.	Jan. 26.	Jan. 27.	Jan. 28.	Jan. 29.	Jan. 30.	Feb. 2.	Feb. 7.
Formaldehyde 1-100.....	None	None	None	None	None	None	None
Formaldehyde 1-10......	None	None	None	None	None	None	None

EXPERIMENT IV.

January 26, 1914, dissected out a very large number of egg masses and divided them into eight lots. After treatment each lot was transferred to a plate of potato agar.

1. Treated the first lot in 3% hydrogen peroxide for 10 minutes.
2. Treated the second lot in 1-100 solution of 40% formaldehyde for 10 minutes.
3. Treated the third lot in 1-10 solution of 40% formaldehyde for 3 minutes.
4. Treated the fourth lot in 40% formaldehyde for 10 minutes.
5. Treated the fifth lot in 1-1000 $HgCl_2$ for 10 minutes.
6. Treated the sixth lot in saturated solution of $HgCl_2$ for a few minutes.
7. Treated the seventh lot in 20% copper sulphate for 30 minutes.
8. Treated the eighth lot in carbon bisulphide vapor for 1½ hours.

TABLE IV.—ACTIVE LARVAE OBSERVED.

Treatment Jan. 26, 1914.	Jan. 27.	Jan. 28.	Jan. 29.	Jan. 30.	Jan. 31.	Feb. 1.	Feb. 3.	Feb. 4.	Feb. 5.
1. Peroxide 3%..................	15	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
2. Formaldehyde 1-100............	None	None	None	None	None	None	None	None	None
3. Formaldehyde 1-10.............	None	None	None	None	None	None	None	None	None
4. Formaldehyde 40%..............	None	None	None	None	None	None	None	None	None
5. $HgCl_2$ 1-1000...................	None	None	None	One	One	One	One	One	One
6. $HgCl_2$ Sat. Sol...................	None	None	None	None	None	None	None	None	None
7. $CuSO_4$ 20%.....................	None	None	None	None	None	None	None	None	None
8. Carbon bisulphide..............	None	None	None	None	None	None	None	None	None

EXPERIMENT V.

February 2, 1914, dissected out a large number of egg masses from knots on tomato roots and divided them into eight lots. After treatment each lot was transferred to a plate of lima bean agar.

1. Treated the first lot in 3% hydrogen peroxide for 30 minutes.
2. Treated the second lot in 1-100 solution of 40% formaldehyde for 15 minutes.
3. Treated the third lot in 1-10 solution of 40% formaldehyde for 15 minutes.
4. Treated the fourth lot in 40% formaldehyde, full strength for 15 minutes.
5. Treated the fifth lot in 1-1000 $Hg\ Cl_2$ for 15 minutes.
6. Treated the sixth lot in a saturated solution of $Hg\ Cl_2$ for 30 minutes.
7. Treated the seventh lot in 20% copper sulphate for forty-five minutes.

8. Treated the eighth lot in carbon bisulphide vapor for 17 hours. The results of this experiment are given in Table V.

TABLE V.—ACTIVE LARVAE OBSERVED.

Treatment Feb. 2, 1914.	Feb. 3.	Feb. 4.	Feb. 5.	Feb. 6.	Feb. 7.	Feb. 9.	Feb. 10.
1. Peroxide 3%........	7	70	Many	Many	Many	Quiet	Appeared dead
2. Formaldehyde 1-100..	None	1	4	21	Abundant	Abundant	Abundant
3. Formaldehyde 1-10...	None	None	None	None	None	None	None
4. Formaldehyde 40%..	None	None	None	None	None	None	None
5. $HgCl_2$ 1-1000........	1	1	1	1	1	None	None
6. $HgCl_2$ sat. sol........	None	None	None	None	None	None	None
7. $CuSO_4$ 20%..........	None	2	2	7	Abundant	Quiet	Appeared dead
8. Carbon bisul. vapor.	None	None	None	None	None	None	None

February 10, 1914, all of the plates of the above series were cleaned up except the 1-100 solution of 40% formaldehyde. This plate was observed from time to time to see how long the larvae would remain alive. March 30, 1914, active larvae were observed.

EXPERIMENT VI.

February 28, 1914, dissected out many egg masses and divided them into four lots. After treatment, each lot was transferred to a plate of potato agar, and the plates sealed shut with paraffin.

1. Treated the first lot by rinsing it in boiled tap water.
2. Treated the second lot in 1-100 solution of 40% formaldehyde for 3 minutes.
3. Treated the third lot in 1-25 solution of 40% formaldehyde for 3 minutes.
4. Treated the fourth lot in 1-10 solution of 40% formaldehyde for 3 minutes. The results of these experiments are given in Table VI.

TABLE VI.—ACTIVE LARVAE OBSERVED.

Treatment Feb. 28, 1914.	March 1.	March 2.	March 3.	March 4.	March 5.
1. Boiled water..............	Larvae present	Larvae present	Larvae present	Larvae present	Larvae present
2. Formaldehyde 1-100........	None	None	None	None	None
3. Formaldehyde 1-25.........	None	None	None	None	None
4. Formaldehyde 1-10.........	None	None	None	None	None

As the conditions under which these laboratory experiments were being conducted differed greatly from those in the field, it was concluded that possibly one or more of these factors was influencing the results, thus making the laboratory results very inconclusive. Perhaps the most obvious difference between the laboratory and the field experiments was the surroundings of the nematodes and eggs after treatment. In the field experiments the eggs were in the soil where plenty of air and moisture could get to them to dilute the various chemicals applied. In the laboratory experiments the eggs were enclosed in petri dishes which tended to keep out the air and moisture, and to keep in the volatile chemicals. This was especially true when the plates were sealed with paraffin. If petri dishes did act as an important factor in causing the chemicals to inhibit nematode egg development, it was thought that this influence might be even greater if the containing vessel were smaller and more tightly sealed. To test this point, we decided to run a series of treatments in culture slides instead of petri dishes.

EXPERIMENT VII.

March 7, 1914, dissected out a large number of egg masses from infested roots and divided them into eleven lots of about 3,000 eggs each. After treatment each lot was transferred to a cover glass and sealed down over a culture slide.

1, 2 and 3. The first three lots were rinsed in sterile water and served as checks on the treatments.

4. Treated the fourth lot in 3% hydrogen peroxide for a short time.

5. Treated the fifth lot in 1-100 solution of 40% formaldehyde for a short time.

6. Treated the sixth lot in 1-25 solution of 40% formaldehyde for a short time.

7. Treated the seventh lot in 1-10 solution of 40% formaldehyde for a short time.

8. Treated the eighth lot in 40% formaldehyde for a short time.

9. Treated the ninth lot in 1-1000 Hg Cl_2 for a short time.

10. Treated the tenth lot in pure liquid carbon bisulphide for a short time.

11. Placed the eleventh lot on a cover-glass and exposed it to carbon bisulphide vapor for ten minutes.

The results of these experiments are given in table VII.

TABLE VII.—ACTIVE LARVAE OBSERVED.

Treatment March 7, 1914.	March 8.	March 9.	March 10.	March 11.	March 12.	March 13.
1. Sterile water	Very many	Very many	Very many	Very many	Very many	Discontinued
2. Sterile water	Very many	Very many	Very many	Very many	Very many	Discontinued
3. Sterile water	Very many	Very many	Very many	Very many	Very many	Discontinued
4. Peroxide 3%	Very many	Very many	All quiet	Quiet	Quiet	Discontinued
5. Formaldehyde 1-100	14	None	None	None	None	Discontinued
6. Formaldehyde 1-25	None	None	None	None	None	Discontinued
7. Formaldehyde 1-10	None	None	None	None	None	Discontinued
8. Formaldehyde 40%	None	None	None	None	None	Discontinued
9. $HgCl_2$ 1-1000	Very many	Very many	Used for a	culturing ex	periment.	
10. Carbon bisul. liq	None	None	None	None	None	Discontinued
11. Carbon bisul. vapor	One	None	Two	None	None	Discontinued

With the exception of the 1-1000 Hg. Cl_2 treatment, the various chemicals all produced more or less of an inhibitory effect on the eggs. And, even where the eggs did hatch, as in the 1-100 formaldehyde and the carbon bisulphide vapor treatment, the larvæ soon died. From this latter fact, it would appear that chemicals were still present in the sealed culture slides to such an extent as to be intolerable to the larvae. The large numbers of larvae that hatched from eggs in the check slides would seem to show that the chemicals were exerting a great influence. This and the previous experiments with closed vessels pointed quite strongly toward the surroundings as an important factor in our laboratory experiments.

In order to see whether the exception, in the case of the 1-1000 Hg Cl_2

treatment of our last experiment, was a normal one, it was decided to repeat this part of the experiment.

EXPERIMENT VIII.

March 9, 1914, dissected out a number of egg masses and placed them in 1-1000 Hg Cl_2 for two minutes. The egg masses were then transferred to drops of agar on four cover glasses, and sealed down over four culture slides. The results of this experiment are given in Table VIII.

TABLE VIII.—ACTIVE LARVAE FOUND.

Treatment March 9, 1914.	March 10.	March 11.	March 12.	March 13.
$HgCl_2$ 1-1000	Very many	Very many	Abundant	All quiet
$HgCl_2$ 1-1000	Very many	Abundant	Abundant	All quiet
$HgCl_2$ 1-1000	Very many	Used for culturing experiment.		
$HgCl_2$ 1-1000	Very many	Used for culturing experiment.		

The results of this experiment appeared to verify those of the previous experiment, and to show that a short exposure to 1-1000 Hg Cl_2 does not keep the nematode eggs from hatching.

As it now seemed probable that the various chemicals exerted an inhibitory effect in closed vessels, it was decided that data should next be obtained on treatments conducted under conditions more nearly like those present in the soil of the field experiments. To accomplish this, the egg masses were placed after treatment in tubes of agar, closed only by cotton plugs. A synthetic agar medium was prepared by adding one and two-tenths per cent of powdered agar and one per cent of glucose to Pfeffer's nutrient plant solution. This on being sterilized and cooled, solidified into a solid medium, through which one could easily see. A number of tubes of this medium were prepared, using about ten c. c. to a tube.

EXPERIMENT IX.

March 14, 1914, dissected out a large number of egg masses from root-knots and divided them into twelve lots. After treatment, each lot was transferred to a tube of synthetic agar while it was still wet with the solution in which it had been treated.

1. Placed the first lot in 1-100 solution of 40% formaldehyde for a few minutes.
2. Placed the second lot in 1-25 solution of 40% formaldehyde for a few minutes.
3. Placed the third lot in 1-10 solution of 40% formaldehyde for a few minutes.
4. Placed the fourth lot in full strength 40% formaldehyde for a few minutes.
5. Placed the fifth lot in 1-500 Hg Cl_2 for a few minutes.
6. Placed the sixth lot in 1-200 Hg Cl_2 for a few minutes.
7. Placed the seventh lot in 1-100 Hg Cl_2 for a few minutes.
8. Placed the eighth lot in full strength "Black Leaf 40" for a short time.
9. Placed the ninth lot in full strength lime-sulfur, 31-32° B., for a few minutes.

10. Placed the tenth lot in the same lime-sulfur as the ninth lot. After being in this solution for a few minutes, the egg masses were transferred to a drop of synthetic agar on a cover glass and sealed down over a culture slide instead of being placed in a tube of synthetic agar.

11. Placed the eleventh lot in full strength commercial sulphuric acid for a few minutes, and then transferred it to a slide of agar.

12. Placed the twelfth lot in 1-100 sulphuric acid for a few minutes. The results of this experiment are given in Table IX.

TABLE IX.—ACTIVE LARVAE OBSERVED.

Treatment March 14, 1914.	Vessel No. of eggs used.	Mar. 15.	Mar. 16.	Mar. 17.	Mar. 18.	Mar. 20.	Mar. 22.	Mar. 24.
1. Formaldehyde 1-100	Tube 2000	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.	Abund.
2. Formaldehyde 1-25	Tube 3000	None	Abund.	Abund.	Abund.	Abund.	Abund.	None active
3. Formaldehyde 1-10	Tube 3000	One	Abund.	Abund.	Abund.	Very many	Very many	Very many
4. Formaldehyde 40%	Tube 3000	None	None	None	....	Two	Abund.	Very many
5. $HgCl_2$ 1-500	Tube 3500	Very many	Very many	Very many	....	Very many	Very many	Many
6. $HgCl_2$ 1-200	Tube 2000	Very many	Very many	Very many	....	Very many	Very many	....
7. $HgCl_2$ 1-100	Tube 2000	Many	Many	Many	....	Many	Many	Many
8. "Blk Lf. 40" full strength	Tube 3000	Very many	Very many	Very many	....	Very many	Very many	None active
9. Lime sul. full strength	Tube 3000	One	Abund.	....	....	Abund.	....	None active
10. Lime sul. full strength	Slide 3000	None	None	None	None	None	....	None
11. H_2SO_4 full strength	Slide 3000	None	None	None	None	None	....	None
12 H_2SO_4 1-100	Slide 3000	None	None	None	None	None	....	None

The results of this experiment as a whole, are so different from those of any of the previous tests that one is strengthened in the opinion that the containing vessel must have been a factor influencing the results. From the table, it will be noted that the treatments which allowed little or no hatching were those where sealed slides were used instead of test tubes. The lime-sulfur treatments give a good comparison of the difference due to the vessel used, because all other conditions were about the same. By referring to Experiment IX, it will be seen that the egg masses were all subjected to the same treatment with lime-sulfur, and then 3,000 eggs were placed in a tube of synthetic agar and 3,000 were placed on a drop of synthetic agar and sealed down over a hollow slide. Abundant larvae hatched from the eggs in the tube, while none hatched from an equal number of eggs in a culture slide. The amount of agar used might be considered as an important factor in bringing out the difference in the result, but by referring to the earlier experiments, it will be seen that where one tube, ten c. c., of agar was spread out over a plate, there was about the same inhibitory effect as in the sealed slide with one drop of agar.

This comparison of the type of vessel used was made for the purpose of trying to account for the great difference between the results obtained in the early experiments and those of later trials. In the early ones was noted a large per cent of inhibition of hatching, while in the later experiments, there was almost no inhibition from treatments with the same, and also with much stronger chemicals. In order to get further data on the inhibitory power of sulphuric acid, as compared with the other chemicals used, it was decided to repeat this treatment, using tubes of agar instead of slides.

EXPERIMENT X.

March 16, 1914, dissected out a large number of egg masses and divided them into three lots. These lots were treated for a few minutes in 1-100 H_2SO_4, 1-50H_2SO_4, and 1-25 H_2SO_4, respectively, and then transferred, while still wet, to three tubes of synthetic agar. The results of this experiment are recorded in Table X.

TABLE X.—ACTIVE LARVAE OBSERVED.

Treatment March 16, 1914.	Number of eggs used.	March 17.	March 19.	March 20.
H_2SO_4 1-100	5000	Abundant	Abundant	Abundant
H_2SO_4 1-50	5000	Abundant	Very many	Very many
H_2SO_4 1-25	5000	Very many	Very many	Very many

The results of this experiment would seem to show that even quite strong sulphuric acid solutions have no more of an inhibiting power than the other chemicals used, when the conditions are made the same.

EXPERIMENT XI.

This experiment was made for the purpose of determining the relative value of carbon bisulphide. March 20, 1914, about twelve thousand eggs were dissected out from knots on lettuce, squash and tomato roots, and divided into two lots of six thousand eggs each. The first lot was placed in pure liquid carbon bisulphide for a few minutes, and then transferred, while still wet, to a tube of synthetic agar. The second lot was placed on a hollow slide, and the slide was then inverted over the mouth of a bottle of carbon bisulphide. After being exposed to the strong vapor for twenty minutes, the egg masses were transferred from the slide to a tube of synthetic agar. The results of this experiment are given in Table XI.

TABLE XI.—ACTIVE LARVAE OBSERVED.

Treatment March 20, 1914.	Number of eggs used.	March 21.	March 22.	March 25.
Liquid Carbon bisulphide	6000	Twelve	Abundant	Abundant
Vaporized Carbon bisulphide	6000	Many	Many	Abundant

From these results it was concluded that treatments with carbon bisulphide, such as the above, do not materially inhibit the hatching of the nematode eggs.

In all of those experiments with tubes of media, the synthetic agar was used. This medium gave a substratum as nearly like that of the soil as could be obtained and still have it clear enough to examine under a microscope, to determine the presence of larvæ. One of the questions that come to mind in the use of this synthetic medium, was that of the possible effect of the various salts of the medium on the chemicals used in the treatments. Did not these various salts tend to act on certain of the chemicals so as to make them lose their power to inhibit the hatching of the nematode eggs? If this occurred in the synthetic medium, one might conceive that it also occurred in the soil and thus might partially account for the failure of certain field experiments. To obtain data on this point, it was decided to run a series of treatments on a medium as free from these various nutrient salts as could be obtained. The best medium that could be devised for this purpose was a plain agar made of distilled water stiffened up with 1.5% of powdered agar. A number of tubes of this medium were made, using about ten c. c. to a tube.

EXPERIMENT XII.

March 21, 1914, a large quantity of eggs was dissected from knots on roots of lettuce and squash plants, and divided into twelve lots. After treatment each lot was transferred to a tube of plain agar.

1. Placed the first lot, of 3000 eggs, in liquid carbon bisulphide for a few minutes.
2. Placed the second lot, of 5000 eggs, on a cover glass and inverted it over the mouth of a bottle of carbon bisulphide for six and one-quarter hours. On removal from the bottle the egg masses were found to be very dry and hard.
3. Placed the third lot, of 4000 eggs, in 1-100 $Hg\ Cl_2$ for a few minutes.
4. Placed the fourth lot, of 3000 eggs, in a 20% solution of $Cu\ SO_4$ for a few minutes.
5. Placed the fifth lot, of 5000 eggs, in full strength lime-sulfur 31 to 32° B. for a few minutes.
6. Placed the sixth lot, of 3000 eggs, in 1-100 H_2SO_4 for a few minutes.
7. Placed the seventh lot, of 3000 eggs, in 1-50 H_2SO_4 for a few minutes.
8. Placed the eighth lot, of 3000 eggs, in 1-25 H_2SO_4 for a few minutes.
9. Placed the ninth lot, of 3000 eggs, in full strength H_2SO_4 for a few minutes.
10. Placed the tenth lot, of 2000 eggs, in 1-100 solution of 40% formaldehyde for a few minutes.
11. Placed the eleventh lot, of 3000 eggs, in 1-25 solution of 40% formaldehyde for a few minutes.
12. Placed the twelfth lot, of 3000 eggs, in 1-10 solution of 400% formaldehyde for a few minutes.

The results of this experiment are given in Table XII.

TABLE XII.—ACTIVE LARVAE OBSERVED.

Treatment March 21, 1914.	No. of eggs used.	March 22.	March 23.	March 24.	March 25.	March 26.	March 27.
1. Liq. carbon bisulphide	3000	None	None	None	One	One	Abundant
2. Vapor carbon bisulphide	5000	None	None	None	None	None	None
3. $HgCl_2$ 1-100	4000	None	None	None	Two	Many	Many
4. $CuSO_4$ 20% solution	3000	None	None	Abundant	Abundant	Many	Many
5. Lime-sulf. full strength	5000	None	None	None	None	Abundant	Many
6. H_2SO_4 1-100	3000	Abundant	Abundant	Used for culturing experiment.			
7. H_2SO_4 1-50	3000	Very many	Very many	Used for culturing experiment.			
8. H_2SO_4 1-25	3000	None	None	None	None	Abundant	Abundant
9. H_2SO_4 full strength	3000	None	None	None	None	None	None
10. Formaldehyde 1-100	2000	None	Abundant	Very many	Very many	Very many	Very many
11. Formaldehyde 1-25	3000	None	One	Two	Abundant	Very many	Very many
12. Formaldehyde 1-10	3000	None	None	Abundant	Abundant	Many	Many

With the exception of the carbon bisulphide vapor treatment for six and one-quarter hours, and the full strength sulphuric acid treatment, it will be observed that the results of the various treatments of this experiment correspond with those of the previous experiments, where tubes of agar were used. As there was no more inhibition of hatching in this last experiment, where plain agar was used, than in the other tests, where synthetic agar was employed, it would seem that the various salts of the synthetic agar did not reduce the inhibitory powers of the chemicals used in the treatments.

EXPERIMENT XIII.

It was thought advisable to repeat the carbon bisulphide treatments to get more definite data than the previous experiments had supplied. March 23, 1914, dissected a number of egg masses from knots on lettuce roots, and divided them into three lots. After treatment, each lot was transferred to a tube of synthetic agar while still wet.

1. Placed the first lot in pure liquid carbon bisulphide for a few minutes.
2. Placed the second lot in carbon bisulphide vapor for one hour.
3. Exposed the third lot to strong carbon bisulphide vapor for sixteen and one-half hours.

The results of this experiment are given in Table XIII.

TABLE XIII.—ACTIVE LARVAE OBSERVED.

Treatment March 23, 1914.	No. of eggs used.	Mar. 24.	Mar. 25.	Mar. 26.	Mar. 27.	Mar. 31.	April 3.
1. Liquid Carbon Bisulphide	5000	Many	Many	Many	Many	Discontinued	Discontinued
2. Carbon Bisulphide vapor	6000	One	Abund.	Abund.	Abund.	Many	Many
3. Carbon Bisulphide vapor 16½ hours	6000	None	None	None	None	None	None

In the case of the liquid treatment and the vapor treatment for one hour, it will be observed that abundant larvæ subsequently hatched from the eggs, while none hatched from the eggs exposed to the carbon bisulphide vapor for sixteen and one-half hours. From this it would appear that the longer exposure to the carbon bisulphide vapor was the only cause of this difference. It was observed, however, that the egg masses dipped in liquid carbon bisulphide, and those exposed to the vapor for one hour did not become dried out as did those exposed to the vapor for sixteen and one-half hours. This observation caused us to raise the question as to what effect the loss of water might have on the results.

EXPERIMENT XIV.

March 24, 1914, dissected out a quantity of egg masses from knots on lettuce roots and placed them in a culture slide. The slide was then placed on the window sill at room temperature and left there until the next day. March 25, 1914, after eighteen and one-half hours of such exposure, the egg masses which had dried down to small, hard lumps, were transferred to a tube of synthetic agar. The results of this experiment are given in Table XIV.

TABLE XIV.—ACTIVE LARVAE OBSERVED.

Treatment March 24-25, 1914.	No. of eggs used.	March 26.	March 27.	March 28.	March 31.	April 3.
Dried at room temp. for 18½ hours......	10,000	None	None	None	None	None

As the egg masses had no surface disinfection, they were not free from viable fungus spores, so by March 31, 1914, the surface of the medium was so over-run by fungi that the egg masses could no longer be distinctly seen. The result of this experiment is the same as that of the long exposure to carbon bisulphide vapor; so it would appear that the drying which the egg masses underwent in the vapor treatment, might have had some inhibitory effect.

In looking over the data on some of the earlier experiments, it was observed that in many cases the writer had subjected the egg masses to the chemicals for longer periods of time than in the later experiments. It was thought that this longer exposure, ten to thirty minutes, might have caused the difference in results. To test this point it was decided to run a series of treatments in which the egg masses should be exposed for thirty minutes or more to the chemical used, before being transferred to the tubes of agar.

EXPERIMENT XV.

March 30, 1914, a large number of egg masses were dissected from knots on squash and tomato roots and divided into seven lots. After treatment, each lot was transferred to a tube of synthetic agar.

1. Placed the first lot, of 5000 eggs, in 31-32° B. lime-sulfur for thirty minutes.
2. Placed the second lot, of 5000 eggs, in full strength "Black Leaf 40" for thirty minutes.
3. Placed the third lot, of 3000 eggs, in 1-100 solution of 40% formaldehyde for forty-five minutes.

4. Placed the fourth lot, of 5000 eggs, in 1-25 solution of 40% formaldehyde for forty-five minutes.
5. Placed the fifth lot, of 5000 eggs, in 1-10 solution of 40% formaldehyde for thirty minutes.
6. Placed the sixth lot, of 5000 eggs, in 20% $CuSO_4$ for thirty minutes.
7. Placed the seventh lot, of 5000 eggs, in 1-50 H_2SO_4 for thirty minutes.

The results of this experiment are given in Table XV.

TABLE XV.—ACTIVE LARVAE OBSERVED.

Treatments March 30. 1914.	No. of eggs used.	Mar. 31.	April 1.	April 2.	April 3.	April 4.	April 5.	April 6.	April 7.
1. Lime-sulfr. 31-32° B.	5000	None	None	One	None	None	Ten	Abundant	Abundant
2. "Black Lf. 40" full strength.........	5000	None	None	None	None	None	Two	None active	None active
3. Formaldehyde 1-100.	3000	None	One	Abund.	Abund.	Abund.	Abund.	Abundant	Abundant
4. Formaldehyde 1-25..	5000	None	None	None	Abund.	Abund.	Abund.	Abundant	Abundant
5. Formaldehyde 1-10..	5000	None	None	None	None	None	12	Abundant	Abundant
6. $CuSO_4$ 20%........	5000	None	None	None	7	Abund.	Abund.	Abundant	Abundant
7. H_2SO_4 1-50.........	5000	5	Abund.	Abund.	Abund.	Abund.	Abund.	Abundant	Discontinued

In the case of the lime-sulfur and the "Black Leaf 40" treatments, the smaller number of active larvœ recorded was due to the fact that the medium was so clouded by the treatments that larvæ could not be distinguished unless they crawled up on the sides of the tubes above the substratum. From the result of this experiment, it would seem that the longer exposure to the chemicals does not affect the ability of the eggs to hatch.

In attempting to subject the eggs to the same conditions that they are under in the actual soil treatments, it would appear that they should be exposed to the chemical for only a short time. In soil treatments we cannot conceive of the eggs being subjected to the chemical except just during the period when the solution is passing down through the soil directly after being applied at the surface. The various vapor treatments are exceptions to the above statement because they exert an influence throughout the time they are present in the soil.

SUMMARY OF THE LABORATORY EXPERIMENTS.

Although the number of experiments conducted so far is not great, the number of eggs used in each experiment was so large that we feel justified in drawing certain conclusions from the results. The results of the earlier experiments were somewhat erratic; but taken as a whole, this series leads one to conclude that the chemicals used cannot be depended upon to control the root-knot nematode, because they do not completely inhibit the hatching of the eggs. We do not feel justified in concluding that this is the only reason for the failure of the chemical treatments in the field experiments, because we have not as yet collected sufficient data on the other theories to draw any definite conclusions regarding them. Stone and Smith (6) found that chemicals failed to inhibit the development of the eggs of certain free-living nematodes. The results of the above-mentioned workers, together with those obtained by the writer with the eggs of the parasitic nematode, *Heterodera radicicola,* indicate that further work along this line may establish the fact that the other parasitic nematodes will be able to survive soil treatments with chemicals for the same reason, namely, that the egg stage in the life cycle is resistant to the chemicals.

DATA ON STEAM STERILIZATION OF SOIL.

During the summer of 1913 it had been intended to conduct experiments on the control of the root-knot nematode by steam sterilization, but it was impossible to get a steam boiler for a sufficient length of time to prepare complete experiments. The writer did succeed in getting a boiler for one day, and so was able to collect some data relative to the depth to which the soil could be heated in a given length of time with equipment such as he had. The method and results of this work as given below, will give an idea of the value of steam, but these results are not sufficient to serve as a basis for definite recommendations. A pan ten feet six inches long, three feet wide, and six inches deep, was used in this work. Steam was furnished by a ten horsepower boiler kept at a pressure of seventy pounds. The soil to be treated was first thoroughly spaded up to loosen it to facilitate the penetration of the steam.

In order to get data on the depth to which the steam penetrated, potatoes were placed in the soil at three places, viz., at the end of the pan where the steam entered, at the opposite end, and at the middle. Holes eighteen inches deep were dug and stakes set in them to mark the location of the potatoes. One potato was placed at the bottom of each hole, eighteen inches below the surface, and the soil was shoveled in until the holes were twelve inches deep. At this depth potatoes were placed in each hole and soil shoveled in until the holes were six inches deep. Potatoes were placed in each hole at this depth, and then the holes were filled until they were but three inches deep. Potatoes were placed at this depth and the holes were then filled up until the soil was level over the whole plot. The pan was then connected up with the boiler and the steam turned on. In about fifteen minutes the steam began to lift the pan out of the soil so that steam escaped from under its edges. To avoid this loss of steam, the pan was weighted down with scrap iron. After thirty minutes of treatment the steam was shut off and the pan removed from the soil. The potatoes in the hole farthest from where the steam entered the pan, were dug first. The potatoes at three inches, six inches, and twelve inches below the surface were well cooked throughout and the one at eighteen inches below the surface was very hot. Next, the potatoes in the middle of the plot were dug up, and all found to be well cooked, even the one eighteen inches below the surface. It was next attempted to dig the potatoes at the end of the plot where the steam entered, but the steam had gouged out such a hole in the soil that it was impossible to locate all of them. The two that were found were well cooked. The soil treated is a very fertile clay loam, with a stiff clay subsoil at about twenty-four inches below the surface.

This steam experiment was next repeated on an adjoining plot of soil exactly as before, except that the steam at eighty pounds pressure was run into the pan for fifteen minutes instead of thirty minutes. At the end of the period the pan was removed and the potatoes were dug. The potato at three inches below the surface was thoroughly cooked. Potatoes at six and twelve inches below the surface were partly cooked. The potato at eighteen inches below the surface was very hot. Of these two treatments, the thirty minute steaming was the better, as judged by the condition of the potatoes. Where the potatoes were well cooked, it is quite reasonable to suppose that the nematodes were killed, but the writer is not certain of this point.*

ACKNOWLEDGMENTS.

The writer is indebted to Dr. E. A. Bessey, Botanist, Michigan Agricultural Experiment Station, for many suggestions and much helpful advice.

To Dr. L. R. Jones, Plant Pathologist, Wisconsin Agricultural Experiment Station, the writer is indebted for much helpful criticism.

LITERATURE.

The literature cited here is chiefly that which has a bearing on this particular problem. For the more general literature on the subject, see the bibliography by Bessey (2).

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Bessey, Ernst A.

(2) Root-knot and its control. Bureau of Plant Industry Bul. 217:7-81. 1911.

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(3) Root-gall. The Agricultural Gazette of New South Wales. Vol. 12, No. 9, pp. 1041-1052. 1901.

(4) The internal structure of the gall-worm. The Agricultural Gazette of New South Wales, Sidney, Vol. 13, No. 10, pp. 1031-1033. 1902.

Rolfs, P. H.

(5) Tomato diseases. Florida Agricultural Experiment Station, Bul. 91; pp. 15-34. 1907.

Stone, George E. and Smith, Ralph E.

(6) Nematode worms. Hatch Experiment Station of the Massachusetts Agricultural College, Bul. 55; pp. 2-67. 1898.

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*NOTE: Observations made by E. A. Bessey in the summer of 1915 on these and similarly treated adjacent lots of formerly badly infected soil show the total absence of root-knot nematodes both one and two years after the steam treatment.

HOW CONTACT INSECTICIDES KILL.

Technical Bulletin No. 21.

III. Relating evidence, further, of certain properties of carbon disulphide, gasoline, and a few other fluids, as well as temperature and some dry powdered contact insecticides, by means of which the insecticidal action of these agents is accomplished after their absorption into the insect tissues, or after mere application;—also brief suggestions for possible practice, by George D. Shafer.

INTRODUCTORY STATEMENTS.

(a) FORMER EVIDENCE.

In a former paper on the subject, "How Contact Insecticides Kill*," it has been shown that many gaseous or volatile contact insecticides mainly become effective after being taken up by the insect tissues. Certain color tests and actual volume measurements demonstrated that gaseous insecticides, (such as H_2S, HCN and NH_4) and the vapor of carbon disulphide, as well as that from many volatile oils (e. g. kerosene, gasoline, benzine, turpentine) are absorbed by the tissues of insects. Much evidence was pointed out which indicated that vapors of gasoline, carbon disulphide and the like, after absorption, accomplish their effect upon insects through some tendency their presence exerts to prevent oxygen assimilation in the tissues.

If the vapors of the insecticides mentioned do interfere with oxygen assimilation, upon what do they act in the tissues to bring about that condition?

At the time the former bulletin was written nothing had been done upon this latter phase of the problem. It is with facts that seem to relate to this phase of the question that the present bulletin has to do. Careful examination was made of the organs of treated insects and many histological studies were made. When an insecticide, such as gasoline, was present in abundance, it was found that after several hours the fatty tissues went more or less into solution. Insects were crushed and an attempt was made to detect changes which carbon disulphide, kerosene, gasoline and the like might have upon the tissue-pulp. It was easy here also to notice the solvent action of gasoline, kerosene and carbon disulphide upon the fats and fat-like substances in the pulp. The action of carbon disulphide upon protein in the pulp could also be seen. The concentrated vapor of carbon disulphide would, in time, coagulate and whiten certain proteins. Egg-albumen readily shows this action of carbon disulphide vapor, after a few hours confinement with air *saturated* at about 68° to 70° F. with that vapor. Studied in this way, however, using only such amounts of the agents in question as were necessary to

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*Parts I and II, Tech. Bulletin No. 11, Mich. Agr. College Exp. Station.

kill insects, there was no visible effect on the tissue pulp which might be held as a sufficient cause for rapid death.

As already pointed out, however, a rise in the respiratory ratio during the time insects were dying, afforded the strongest evidence of an inhibition of oxygen assimilation. It was decided, therefore, to determine the respiratory exchange of fresh insect tissue pulp and to see whether this exchange became influenced by gasoline, for example, in the same manner as had already been found for insects themselves. That the pulp does have a decided respiratory exchange, and that this is influenced by gasoline vapor in the same manner as the latter influences the respiration of insects may be seen by comparing table I-A with table V of part I, Tech. Bull. No. 11.

TABLE I.

A.

Extract pulp of tissues of *Passalus cornutus*.	Treatment.	Temperature.	Respiratory period.	$\frac{CO_2}{O_2}$
5 c. c.	Gasoline	24.2° C	16 hrs	$\frac{2.1}{1.2} = 1.7$
5 c. c. same sample	None	Same	Same	$\frac{2.8}{3.4} = 0.82$
5 c. c.	Gasoline	24.2° C	7½ hrs	$\frac{0.9}{0.4} = 2.2$
5 c. c. same sample	None	Same	Same	$\frac{0.5}{1.0} = 0.5$
5 c. c.	Gasoline	25.4° C	16½ hrs	$\frac{3.1}{1.3} = 2.3$
5 c. c. same sample	None	Same	Same	$\frac{4}{5} = 0.8$

B.

Extract pulp of tissues of *Passalus cornutus*.	Treatment.	Temperature.	Respiratory period.	$\frac{CO_2}{O_2}$
5 beetles (uninjured)	None	20.8° C	1 hr	$\frac{3.2}{4.49} = 0.71$
Same 5 beetles	Opened and digestive tracts removed.	21° C	1 hr	$\frac{0.89}{0.8} = 1.1$
5 beetles	“ “	20.4° C	18 hrs	$\frac{6.4}{7.9} = 0.81$
5 beetles	“ “	20.8° C	6 hrs	$\frac{2.7}{2.9} = 0.9$

Gasoline was selected for making this test because of all the volatile insecticides employed, it permitted of the most accurate volumetric determinations of its own vapor, and of the oxygen, carbon dioxide and nitrogen present at the beginning and at the end of the test. The apparatus and the method employed for making the gas determinations has been described in Part I of the former bulletin. The insect-tissue pulp was contained in a small, sterile, open glass stender dish which floated on the mercury in the respiration container. The pulp, or crude tissue-extract, was prepared as follows: The insects were thoroughly cleaned with absolute alcohol and a cloth. In the case of *Passalus cornutus,* which was mostly used, the wing-covers and wings were first removed. Then the digestive tracts were carefully removed entire, and discarded. The remainder of the tissues—blood, fat, muscles, nervous tissue, etc.—became thoroughly "ground up" in a mortar with a little distilled water.

It will be noticed that the respiratory ratio of the pulp or water extract of insect tissues proved to be rather higher, often, than was the case for healthy, uninjured beetles. A few respiration experiments were run, using insect bodies from which the digestive tracts had been removed. The ratio of carbon dioxide given off to oxygen taken up was in this case, also, a little higher usually than the ratio for normal healthy beetles. (See B, table I). Mechanical injury, through crushing without external mutilation, or through pithing the beetles with a hot needle, however, gave a ratio for the respiratory exchange lower than that of healthy normal beetles. But as has already been pointed out, when air saturated with gasoline vapor was used either with the insects themselves, with the tissue-pulp or with the crude water extract, it regularly caused a decided rise in the respiratory ratio above that given by the same insects, tissue pulp, or crude extract. Thus it began to appear as if whatever bodies were present in the living insect tissues to start and carry forward the respiratory process—these were able to maintain themselves as "respiratory bodies" (with limited activity) for a time, at least, in the insect tissue pulp and in the crude extract of the pulp, where the effects of the insecticides in question might still be studied.

(b) OXIDASES, CATALASES AND REDUCTASES IN ANIMALS AND PLANTS.

In the pulp and in the water extract of various tissues of many vertebrate and other animals and in many plant tissues, workers have described enzymes which are able not only to carry forward oxidation processes in the pulp or extract itself, but also to initiate or accelerate the oxidation of certain other bodies, such as gum guaiac, hydroquinone, tyrosine, etc., when these are added in solution to the extract. Such enzymes have received the general name of oxidases. It is not the purpose here to give a discussion of oxidasic enzymes, their kinds and possible functions in the living tissues in connection with other enzymes or enzyme-like bodies; but a short statement will make clear the import of the experiments which follow in this connection. None of the oxidases have been obtained in a known pure and isolated form, yet much has been learned of their properties, and of their more or less specific action, so that they have generally received names according to the kind of body or bodies upon which they have been found to act—as alcoholases, aldehydases, phenolases, or laccase, tyrosinase, etc. Associated generally, if not always in pulp or tissue-extract with oxidases, various workers have found peroxidases, catalases, and reductase (or reductases). The peroxidases of tissue extracts (when they clearly show themselves present) are substances which activate peroxides—for example they cause hydrogen peroxide to change in such a way that its oxygen may became transferred to guaiac, causing oxidation of the latter to guaiac blue. Peroxidases serve as activators merely; they do not cause the liberation of free oxygen from the peroxides. Indeed an oxidase is now looked upon by most workers in this field as an organic peroxide, or an oxygenase (i. e. a substance capable of quickly forming an organic peroxide by uniting with oxygen from air) working with a peroxidase. The alpha and beta catalases, as demonstrated by Loew, are enzymes which are capable of breaking down H_2O_2 into molecular oxygen and water, the oxygen coming off in bubbles. Finally, tissue pulp from plants and from animals has been found to possess a more or less strong reducing power. This power has been generally attributed to reducing enzymes called reductases. Knowledge of the functions and properties of the enzymes mentioned above is, as yet, very incomplete. Satisfactory proof has not been obtained in some cases, and there are those who believe that reductases and catalases are not enzymes at all. As experiments and observations accumulate, however, there seems to be a growing number, among those actively engaged in investigation of the subject, who believe that in the oxidases, catalases, and reductases we have to do with a part, at least, of the machinery which accomplishes oxidations and respiration in the protoplasm of living cells. Alexis Bach, for example, has gone so far (in 1913)[*], in a discussion of oxidising and reducing enzymes, as to express his belief in their role in the process of respiration rather definitely. E. F. Armstrong in the "Journ. of the Chem. Soc. 104, Part I, p. 543, abstracts Bach's conclusions as follows:

"(1) In order to utilize the oxygen of the air to effect oxidation, the cell produces an enzyme (an oxygenase)—a substance which is readily oxidized, fixing molecular oxygen to form a peroxide. (2) A second enzyme (the peroxydase) accelerates the oxidizing action of the peroxides, acting on them in the same way as ferrous sulphate does toward H_2O_2. (3) The peroxides are readily transformed by hydrolysis into H_2O_2 which is also formed as a primary product during hydrolytic oxidation. Owing to its rapid rate of diffusion, this accumulation of H_2O_2 might damage the cell protoplasm. To guard against this, the cell produces an enzyme—catalase, which rapidly decomposes H_2O_2 into water and inert O_2. Catalase thus acts as a regulator of the respiratory process. (4) To effect hydrolytic oxidation, an enzyme-perhydridase—is present which accelerates both oxidation and reduction just as do the metals of the platinum group. The reductase consists of the enzyme, water and an oxidisable substance which fixes the oxygen derived from the water, leaving the hydrogen free to effect reduction."

In view of the importance which physiologists begin to attach to oxidizing and reducing bodies in tissue extracts of animals and plants, and because of the influence which certain of the contact insecticides are now known to have upon the respiratory exchange of insects, it seemed worth while to investigate these bodies in insect tissue extract and to study the effect of gasoline, carbon disulphide, and some other contact insecticides upon the activity of those found to be present.

(c) OXIDIZING AND REDUCING BODIES IN INSECT TISSUE PULP OR EXTRACT.

The method used in preparing insect tisue pulp for study has already been described. In preparing the crude extract the pulp was ground up with a small amount of sterile distilled water—usually about twelve to fifteen cubic centimeters to five or six adult specimens of *Passalus*

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[*] (Arch. Sci. phys. nat., 1913, vol. 35, 240-262).

cornutus. Then the extract was pressed out through Swiss muslin. The crude extract obtained in this way was whitish or creamy in appearance, at first, due to fat and very tiny particles of tissue which came through the muslin. When this extract was filtered through heavy filters under twenty to twenty-five pounds pressure, a clear or slightly straw-colored filtrate was obtained, and (on the filter) a considerable residue. When either the crude extract or the filtrate was allowed to stand for a time, the surface in contact with the air turned dark while the deeper parts of the fluid remained as at first for hours—for more than a day if kept cool or treated with a *little* of some weak antiseptic like chloroform, sodium fluoride solution, toluol or ether. Whenever work with the extract extended over several hours, some such antiseptic was used provided the nature of the experiment would permit. If to about 1 c. c. of the crude extract a few (2 to 5) drops of a saturated solution of alcoholic guaiac were added, the milky mixture would begin to show a tinge of blue within one or two minutes, and would gradually develop a beautiful deep blue coloration. When about 1 c. c. of a standard hydroquinone solution* was added to 3 c. c. of the extract, it slowly began to turn reddish brown; and after several hours, the entire mixture appeared very dark brown or perhaps almost black, giving off a decided odor of quinone. Vernon's alpha-naphthol paraphenylene-diamine mixture† was tried, and this, the crude extract rapidly oxidized to the blue indophenol. Finally, the extract was able to slowly oxidize tyrosine (Merck) until after a few hours one obtained a heavy black or melanic pigment. It was interesting to drop a small pinch of tyrosine crystals into a little extract from *P. cornutus* tissue, and then watch the black coloration develop about it. The extract clearly possessed oxidasic properties. Moreover, the filtrate and the washed residue left from filtering the crude extract under pressure gave the reactions showing the presence of oxidases. That is, oxidases soluble in water and insoluble in water were present. Likewise two catalases, one soluble in water and going with the filtrate, the other insoluble in water and remaining in the washed residue, were found to be present as first described by Loew‡ in the tobacco plant, and both were very active in liberating bubbles of oxygen from hydrogen peroxide.

Some of the fresh extract which had just darkened was confined in the absence of oxygen, and it became rapidly changed back to the appearance it had before it had darkened. If a few drops of a methylene blue solution were added to some of the extract and then the latter were confined from the oxygen of the air, the blue color became entirely reduced. Reducing bodies, therefore, seemed to be present; and besides, the reduction of methylene blue took place whether it was confined with the filtrate of the crude extract or with the washed residue. Thus, oxidases, catalases, and reducing bodies were all found to exist in the pulp and in the crude water extract of *P. cornutus* in two forms, one being soluble and the other insoluble in water. It therefore seemed desirable to make a further study of these oxydasic and reducing bodies of *P. cornutus* and to determine the effect of some of the contact insecticides upon their activity. How, for example, would gasoline vapor or the vapor of carbon disulphide affect the rate at which the crude water extract could oxidize a solution of hydroquinone? When present in concentrated amounts, the rate at which oxygen was absorbed by insects and by crude insect tissue-extract was lowered by these insecticides. Would they reduce the rate at which the oxydases in the extract caused guaiac or hydroquinone to become oxidized?

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*This standard solution was made up by dissolving 1.1 grams of hydroquinone in 100 c. c. of distilled water.

(i. e. $\frac{m}{10}$ hydroquinone.)

†Vernon, H. M. The Quantitative estimation of Indophenol Oxidase of Animal Tissues. The Journal of Physiology, Vol. XLII., Nos. 5 and 6, pp. 402-427.

‡Oscar Loew: Report No. 68 Div. of Veg. Phys. and Path., U. S. Dept. of Agr., 1901.

THE EFFECT OF GASOLINE AND SOME OTHER CONTACT INSECTICIDES UPON THE OXIDASE, CATALASE, AND REDUCTASE ACTIVITY IN EXTRACTS OF THE TISSUES OF *P. CORNUTUS*.

(a) EFFECT UPON OXIDASIC ACTIVITY.

It has been pointed out that both soluble and insoluble oxidases were found to be present in the extract of *P. cornutus*. The insoluble oxidase (oxydone*) remained in the mixed residue on the pressure filter after filtering the crude extract, while the soluble form went through in the clear or straw-colored filtrate. When the latter was treated with alcohol or saturated with ammonium sulphate until the proteins were thrown down, the oxidase separated with them and could be filtered out. The oxidasic activity of this alcoholic or ammonium sulphate precipitate could be preserved for hours or even days, if the precipitate were kept moist and cool; but drying, even at room temperature, almost if not entirely destroyed the activity of the oxidase in a few hours. On the other hand, when the washed residue containing the oxydone was moistened after having been dried at room temperature for 36 hours or even longer, it exhibited oxidasic action toward alcoholic guaiac almost undiminished. Moreover, in the dry condition, the oxydone was very resistant to heat. It could then be kept at 90° to 100° C. for an hour without destroying all of its activity. When moist, as in the crude extract, however, both the oxidase and the oxydone were destroyed if kept at a boiling heat for 10 minutes; and nearly all oxydasic activity was destroyed if a crude extract were kept at 80° to 81° C. for 15 minutes. When kept at 68° to 69° C. for one hour, such an extract was 5 to 6 times longer in oxidizing alcoholic guaiac than a check kept at room temperature for the same time. In making this comparative test with alcoholic guaiac, the same amount of extract was used for the check as for the heated portion, and at the end of the test period a certain number of drops of the guaiac solution were added to each portion. Then the time required to oxidize the guaiac in the treated and untreated extracts to the same depth of blue coloration was noted. This was a method by which only well marked differences might be compared, but by its use one could easily see also that solutions of hydrochloric acid, borax, sodium fluoride, nicotine (to-bak-ine) and ammonia all exerted a more or less harmful influence upon the ability of the crude extract to oxidize guaiac (exposed to the air) when they were added in small amounts. Both the oxidase and the oxydone were affected. The influence of carbon disulphide, gasoline, and hydrocyanic acid gas were studied in the same manner. In the case of carbon disulphide and gasoline, the influence of both the vapor and the liquid of each fluid was studied—using the vapors to saturation in air, and the liquids at the rate of three drops to 2 c. c. of extract thoroughly mixed to an emulsion.

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*Insoluble oxydases in animal tissues are referred to as "oxydones" by Batelli, and (Mlle) Lina Stern, Biochem. Zeitsch. 1913, 52, p. 226. Rev. in J. of Chem. Soc. vols. 103-104 pt. i, p. 929.

The work of these investigators did not come to the notice of the author until early in 1914, when this phase of his own work was nearly finished—having been begun in 1912.

Carbon disulphide deterred the oxidation of guaiac by the extract greatly;—sometimes the blue coloration did not begin to develop until after two hours, when the extract had been treated with the concentrated vapor or with the liquid for a few hours before testing. The influence of carbon disulphide was most marked when the extract was rich in fat-emulsion.

The influence of concentrated gasoline vapor on the oxidasic properties of an extract, as studied by the aid of alcoholic guaiac, was never very decided. However, the liquid gasoline first used appeared quite destructive to the oxidase, but that sample of gasoline was later found to be slightly acid in reaction; and when this acidity was rendered just neutral, the liquid gasoline then acted scarcely more harmfully than the concentrated vapor. In fact if either the vapor or the liquid gasoline were used with perfectly fresh milky extract (rich in fat) it seemed to hasten the bluing of guaiac—or to hasten the darkening of the extract itself on standing alone in air.

In the case of hydrocyanic acid gas, it was found that if an extract were tested immediately after being removed from the treatment, the guaiac blued very much more slowly than in the check. If, however, the treated extract were allowed to stand in air for an hour or so until it became free from the odor of hydrocyanic acid, the guaiac blued almost as rapidly upon being added as in the check extract.

Borax (3 grams in 100 c. c. distilled water) was very destructive to both the oxidase and the oxydone, when a little of the solution was shaken up with the extract and allowed to stand for a few minutes.

Sodium fluoride, in saturated solution, was used. It retarded the development of guaiac-blue when added in considerable amounts to an extract, but even 1 c. c. of the solution mixed with 1 c. c. of the extract did not prevent the development of the blue coloration after an hour or two. When added in only small amounts to a fresh extract, sodium fluoride solution seemed to hasten the bluing of guaiac. Likewise chloroform and ether did not seem to injure the oxidasic activity of the tissue extract toward alcoholic guaiac, except very slightly when they were used in large amounts and thoroughly shaken up with the extract.

This study with alcoholic guaiac was instructive, but a method was sought which would show by *volume measurements* of the oxygen taken up just what influence carbon disulphide and gasoline (for example) had upon the rate at which oxygen was absorbed by insect-tissue-extract plus some other substrate than guaiac. Hydroquinone solution was selected as the substrate to be oxidized because it was easy to keep a comparatively constant, clear, standard solution for some time, and because as the oxidation to quinone proceeded, the color of the solution changed progressively from a reddish to a darker and darker coloration. Thus, a color check was afforded, upon the volume of oxygen used in the case of treated (with insecticide) and untreated extract samples. (See Fig. 1, Plate I.) So many factors were involved that it was necessary to use extreme precaution in order to be at all sure that a difference in volume of the oxygen absorbed by hydroquinone-extract-mixture in air and hydroquinone-extract in gasoline-vapor-air was due alone to the influence of gasoline vapor. It was necessary always to thoroughly mix a fairly concentrated extract and then to remove two equally measured samples for the experiment at as nearly as possible the same time. Furthermore, exactly equal measures of a standard hydroquinone solution must be added to the two samples at the same time, and then the tests with the two equally prepared mixtures must necessarily be run (the one in air and the other in gasoline-air) under like conditions of temperature for the same period of time. It would not do to run the tests for equal periods, merely. They must cover the same period as nearly as that might be made possible. The reason for these precautions, if not apparent here, will be noticed later in the discussion. Another difficulty presented itself. Oxygen was absorbed rather slowly in the tests, and so it seemed advisable to find some method of measuring directly the entire amount of carbon dioxide that might be given off, as well as the entire amount of oxygen taken up, rather than to depend upon percentage estimations from samples. No method was available for removing and accurately estimating carbon disulphide vapor from air used in a test, and so it seemed necessary to be able to measure the oxygen taken up and the carbon dioxide given off *in the presence* of the insecticide employed during the test. Finally, an apparatus was devised which complied very well with the requirements just outlined. The essential features of the apparatus are represented in Figure 1, and a brief description follows here.

The apparatus (Fig. 1), consisted of two systems which were almost exact duplicates, each made up of a gas-burette "a" connected with a mercury-mug "b"; a gas-container "c"; a potash absorption flask "d"; a mercury manometer "e"; a burette "f" (graduated to O. 1 c. c.) for the hydroquinone solution; and a circulating pump "g". The gas container was of about 300 c. c. capacity, with two two-way cocks above and a wide mouth (2½ inches) beneath. The wide rubber-stopper for this container was connected with a mercury-mug "h", and a hooked U-tube also passed from the stopper to connect with the hydroquinone burette "f". Mercury could thus be used not only to seal the mouth of the gas-container, but to float the stender dish up under the hooked end of the U-tube. The gas-burette of each system was connected by tubes (with airtight sealed joints) through the corresponding gas-container, absorption-flask, mercury manometer and circulating pump of its system, as represented in the figure. Between the "pump-gas-container connecting tube" and the "absorption-flask-pump connecting tube" was a cross tube with a stopcock "St." Fig. 1. This cock was kept closed when the pumps were running. It was opened as soon as the pumps were stopped, and always, before the manometers were adjusted, the circulating wheel of each pump was given a quarter turn backward. Thus, any air that might be compressed in a pocket was released into the upper air-chamber, leaving the pockets filled with mercury. The circulating pump of each system was actuated by belts from the same double pulley of a reducing gear "j", which was run by a small motor not shown in the figure. It was thus possible to start and stop the pumps (which were duplicates) at the same time and to run them at the same speed. There was not found, on the market, a small pump in which the gas to be circulated did not come in contact with the boxing of the pulley-journal of the

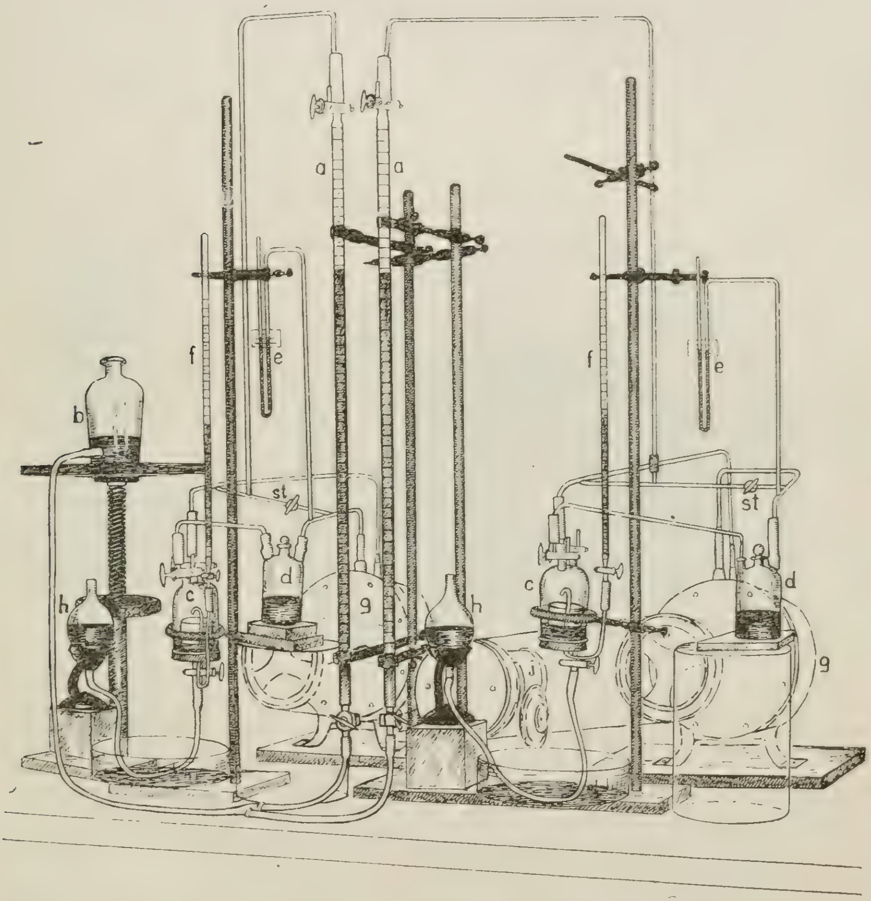

Fig. 1. Apparatus used in determining the influence of gasoline and carbon disulphide upon the absorption activity for oxygen of insect tissue-extract plus hydroquinone solution. (Duplicate systems) a = gas burettes; b = mercury mugs; c = gas-containers; d = potash absorption flasks; e = mercury manometers; f = burettes for hydroquinone solution; g = circulating pumps; h = mercury mugs; j = reducing gear.

pump. In these experiments, it was necessary to *know* that no leak or gas exchange could take place at that point. The two circulating pumps represented in Fig. 1 were, therefore, designed to meet the necessity. Each pump was filled with mercury to a certain level as shown by line "a-c", Fig. II. The circulating wheel "w" pointed out in the same figure was made to revolve in the mercury in the direction of the large arrow. Each pocket in the wheel thus carried gas from the air-chamber in the upper part of the pump down into the mercury to the position "p", when the air emptied toward the center (due to its tendency to rise in the mercury) and came out into the outlet tube "o" as shown in Fig. II B. The pump was therefore able to circulate air against a pressure equal to the mercury-height "s-t", and the confined gas in the pump could not come in contact with the pulley journal "j" under any circumstances, since the lowest level "s", to which the mercury could be brought, was higher than the pulley-journal. As a precaution, a small cup was set beside each pump (when in use) just beneath the boxing "k". If a mercury leak should have occurred from this point, the volume of the leak could have been known at once from the mercury caught in the cup. When the apparatus was set up, much trouble was experienced in getting all connections sealed gas-tight. Tests were not begun with the extract, however, until the apparatus was able to stand, for several hours, under a pressure greater than any that might occur in the regular experiments, without showing a measurable leak. Moreover, test experiments were run with samples of the same extract in air in both gas-containers of the apparatus until comparatively uniform results

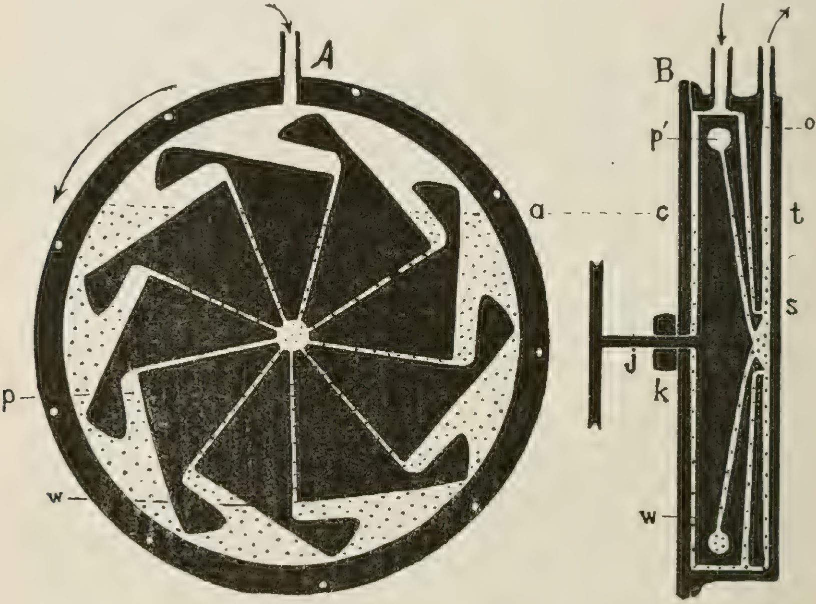

Fig. II. Diagrammatic projections of the working parts in gas-circulating-pump (see "g" Fig. 1). A = Side-projection; B = Edge-projection; a-c = level of mercury; w= circulating wheel; p = position of air pocket when it empties toward the center; p' = air pocket; o= outlet tube; s = bearing around the common central outlet for the air pockets in the circulating wheel; j = pulley journal.

were given. The working difference which might occur between the two systems of the apparatus was about 0.2 c. c. When a test to obtain the influence of gasoline-vapor or carbon disulphide vapor upon the hydroquinone-oxidase activity of insect tissue extract was to be run, equal samples from the same tissue-extract were placed in each of two sterile stender dishes of 36 m. m. diameter, and the dishes were introduced into the two gas-containers "c." "c.", Fig. I. Mercury seal was made at the mouth of each gas-container, and the U-tubes were connected with the hydroquinone burettes. Then, by means of the mercury-mug and the free opening of one of the two-way cocks of one gas-container, as much insecticide vapor as was wanted could be introduced from a separate stock-container of concentrated insecticide vapor. After that, the cocks of the gas-containers were opened to the outside an instant until both mercury manometers read level. The temperature was recorded. Then the cocks were all properly set and the motor started, so that in the two systems the gas or air was made to circulate until it was uniformly mixed. The motor was stopped and started in this way several times (pressure adjustments being made between times, if necessary) until the manometers stood level after each short interval. The cocks of the gas-containers were then quickly opened to the outside, and hydroquinone solution was carefully let down from the burettes until it reached the openings of the hooked U-tubes above the stender dishes in the two containers "c." "c." A measured amount, usually 2 c. c. of hydroquinone solution to 5 c. c. of the tissue extract, was measured into each extract stender dish. Test was again made to see that the pressure manometers stood level and then both cocks of each gas-container were closed. The temperature was again noted. The barometer reading and the readings of the two gas-burettes were recorded. The apparatus then stood during the desired period of the test in a room where the temperature varied but little—and only very slowly—and one could be sure that both systems of the apparatus were at the same temperature when readings of the gas-burettes were made. At the end of the test period, the cocks at the top of the gas-containers were turned so as to connect each container with its own system. The mercury in each gas-burette was quickly manipulated so as to bring the mercury manometers level, and the readings of the two gas-burettes were taken. Then the cocks "st" and "st′" were closed and the pumps were started. The gas or air in each system was thus made to circulate through the absorption flasks until trial showed that the readings of the gas-burettes (after short runs of the pumps) were constant, when the two manometers "e" and "e" stood at zero. The reading of each gas-burette was then again recorded. Thus there were three gas-volume readings for the system containing the insecticide-treated extract and three for the check. The first reading in each set showed the constant volume of the gas under certain recorded conditions of temperature and barometric pressure; the second showed the volume after oxygen absorption (i. e. by the extract containing hydroquinone solution), before any carbon dioxide had been removed; and the third reading gave the volume after the carbon dioxide produced during the experiment period had been circulated through the hydroxide flask and absorbed. The readings were all reduced to the volume which would be given at 0°C. and 760 m. m. mercury pressure so that they might be safely compared. The second reading, then, minus the third (in each set of reduced readings) showed the volume of carbon dioxide produced during the period; and since no carbon dioxide was present at the beginning, the first reading minus the third gave the volume of oxygen that had been absorbed during the test. The volume of oxygen absorbed in the case of the insecticide-treated "extract plus hydroquinone" and the volume of oxygen absorbed by the untreated "extract plus hydroquinone" could thus be compared directly; and it is believed that any difference must be attributed to the influence of the insecticide present, since other conditions were kept as nearly as possible the same.

Checks tried separately had shown that gasoline and carbon disulphide vapors were not appreciably affected by the potassium hydroxide solution used, and that they did not interfere with its absorption of carbon dioxide.

The records of a test are given here as they were kept for a regular experiment:

Exp. 7. Used 5 c. c. of an extract (made from 4 large "white grubs" in 20 c. c. distilled water, plus 3 drops of Toluol) in each of the two containers—right and left.

Ran pump at intervals until readings became constant. Added 2 c. c. or $\frac{N}{100}$ hydroquinone solution to each. Ran pumps short interval—readings were constant.

Started 17 Aug. 1912, 4:45 P. M.
Ended 18 Aug. 1912, 8:00 A. M.

At start —Bar. =740 m.m.; Temp. =19.3° C.
At end — " =734 m.m.; " =20.4° C.

Ext. =Left-hand system (CS_2—treated).	Ext. =Right-hand system (no treatment).
Gas-burette reading	Gas-burette reading
27.5 c.c.	20.5 c.c.
30.5	23.5
27.5	20.5

Readings reduced to 760 m.m. mercury pressure and 0°C:—
Left-hand system (CS_2—treated).

430 c.c. =Volume of left-hand system, exclusive of gas-burette.
27.5 c.c. =Volume of gas in left-hand gas-burette.

457.5 c.c. =Total volume of left-hand system at start.

$$\frac{457\ (740-16.655)273}{760(273+19.3)} = 406.6 \text{ c.c. vol. at start (reduced).}$$

430.0 c.c.
30.5

460.5 =Total vol. at end of test; before CO_2 had been absorbed.

$$\frac{460.5\ (734-17.826)273}{760(273+20.4)} = 403.7 \text{ c.c. Vol. before } CO_2 \text{ had been absorbed (reduced).}$$

430.0
27.5

457.5 =Total vol. at end of test (after CO_2 was absorbed).

$$\frac{457.5(734-17.826)273}{760(273+20.4)} = 401.1 \text{ Vol. at end of the test (reduced).}$$

Then 406.6
401.1

5.5 c.c. O_2 absorbed during test by the "extract plus hydroquinone" in the presence of CS_2 — vapor in air.

and 403.7
401.1

2.6 c.c. CO_2 given off during test in the CS_2—treated gas-container.

Right-hand System (check).

420.0 c.c. =Vol. of right-hand system, exclusive of gas-burette (at start.)
20.5 =Vol. of right-hand system gas burette.

440.5

$$\frac{440.5(740-16.655)273}{760(273+19.3)}=394.7 \text{ c.c. Vol. at start (reduced).}$$

420.0 c.c.
23.5

443.5 c.c. =Total vol. at end of test (before CO_2 had been absorbed.)

$$\frac{443.5(734-17.826)273}{760(273+20.4)}=389.3 \text{ c.c. above vol. (reduced).}$$

420.0 c.c.
20.5

440.5 c.c. =Total vol. at end after CO_2 had been absorbed.

$$\frac{440.5(734-17.826)273}{760(273+20.4)}=386.6 \text{ c.c. above volume (reduced).}$$

Then 394.7
386.6

8.1 c.c. O_2 absorbed during test by the check.

and 389.3
386.6

2.7 c.c. CO_2 given off during test by the check.

$8.1-5.5=2.6$ c.c. more O_2 abosrbed in case of the check (i. e. not treated with CS_2—vapor).

Note was kept of twenty-one experiments carried out in adjusting and in learning to manipulate and use the apparatus to obtain trustworthy results. It was found that the greatest care must be taken to be sure that the two systems of the apparatus were at the same temperature. A door, opened for a short time to admit air of a different temperature from one side of the room, could cause a variation in the volume of the gas in the two systems which would entirely vitiate results if readings were made at that time. It was discovered also that a variation in the influence of the insecticide-vapor occurred, depending on whether the extract were used immediately after it had been prepared, or not until a few hours later—this seemed to be especially true when gasoline was used. This fact served to emphasize the necessity of taking, from the prepared extract, the sample to be treated with the insecticide and the check sample at the same time, and of carrying out the tests with the two during the same period—although the reason for the variation mentioned above was not appreciated until later in the investigation. If the insecticide vapor in the air used in an experiment was near saturation, then it was necessary not to allow the room temperature to fall below that at which the experiment was started. Otherwise some of the insecticide-vapor would be condensed and the vapor tension of the gas-mixture changed. Correction for change in vapor-tension of water vapor due to a change in temperature could be readily made, but no method was at hand for making a similar correction in case of gasoline or carbon-disulphide vapor when the apparatus illustrated by Fig. I was being used. Furthermore, it was found that high concentrations of the insecticide vapor were necessary to show a marked influence, especially if the water content of the extract were high.

After the preliminary tests, written record was kept of more than thirty experiments, including cautionary check experiments, which were made to get the influence of gasoline and carbon disulphide vapors upon the oxygen absorption activity of "insect extract plus hydroquinone solution". Some of these experiments were performed during as many as three successive periods. In all of these tests unless otherwise stated, the stender dish of each gas-container held 5 c. c. of insect tissue extract from the same stock extract mixed with 2 c. c. of a standard hydroquinone solution (1.1 grams of hydroquinone in 100 c. c. of distilled water.) Representative results of these experiments are given in table II.

The first ten results in the table relate directly to the influence of carbon disulphide or of gasoline vapor upon the activity of "insect tissue extract plus hydroquinone solution" for oxygen absorption.

A study of the table will show that the higher concentrations of insecticide vapors caused a marked reduction in oxygen avidity under that shown by the corresponding checks. Weak concentrations of the insecticides, on the other hand, seemed to accelerate, very slightly, rather than to retard oxygen absorption. One may appreciate the influence of the insecticide, perhaps, better by comparing the total sum of the oxygen absorptions in the insecticide chamber with the total corresponding absorptions in the check gas-chamber.

In case of carbon disulphide vapor the ratio is 6.7 c. c. to 19.1 c. c. In other words, only about 7/20 as much oxygen was absorbed during the series of tests in the carbon disulphide chamber as was absorbed in the check gas-chamber with air alone present. For gasoline-vapor the ratio is 10.2 c. c. of oxygen absorbed in the gasoline chamber to 13.9 c. c. in the pure air chamber (i. e. about 7/10); and if those tests in which the vapor was in high concentration are considered alone, then barely over one-half as much oxygen was absorbed in the gasoline-vapor chamber. The ratio of carbon dioxide given off to the oxygen absorbed by the mixture of "insect tissue-extract and hydroquinone solution" as expressed by the totals for the insecticide-treated samples is 0.8+, and the similar ratio as expressed by the totals for the corresponding checks is 0.4. That is, the respiratory ratio of the "tissue-extract plus hydroquinone solution" proved to be decidedly higher in the presence of strong gasoline or carbon disulphide vapors than was found to be the case in pure air. Now, as has already been mentioned, an oxidase in the insect tissue-extract is able, it is believed, to accelerate the oxidation of hydroquinone to quinone and water—the quinone showing its presence by its odor and by a change in color of the extract-solution. If, then, an oxidase in the extract does cause that kind of an oxidation of hydroquinone, it would naturally follow that an extract to which the latter had been added might take up more oxygen in a given period than it otherwise would, and that the added hydroquinone would therefore decrease the respiratory ratio $\left(\frac{CO_2}{O_2}\right)$ of the extract. Note the ratio 0.4 above, which is much below that found for healthy beetles in pure air—the latter ratio being about 0.75. The last three results given in Table II are precautionary checks on the manner in which hydroquinone is oxidized by extract of the tissues of *P. cornutus*. To each of the stock

TABLE II.—INFLUENCE OF GASOLINE AND CS_2 VAPORS UPON THE ABSORPTION ACTIVITY FOR OXYGEN OF INSECT TISSUE-EXTRACT PLUS M-10 HYDROQUINONE SOLUTION.*

*(1.1 grams of hydroquinone in 100 c. c. of dist. water.)

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Exp No.	Stock extract from:—	Insecticide.	Period.	Insecticide chamber.		Check gas-chamber.	
				O_2 used.	CO_2 given off.	O_2 used.	CO_2 given off.
1.	3 large white grubs and 20 c. c. water....	CS_2, rather low concentration.........	29 hrs......	5.5 c. c....	2.2 c. c....	6.4 c. c....	1.6 c. c.
2.	3 white grubs, 15 c. c. water. (1 hr. old).	CS_2, high concentration..............	21 hrs......	0.3 c. c....	1.9 c. c....	4.9 c. c....	2.4 c. c.
3.	4 white grubs, 20 c. c. water (Ext. 5 hrs. old)............................	CS_2, nearly saturated................	16 hrs......	0.3 c. c....	2.8 c. c....	3.9 c. c....	1.4 c. c.
4.	4 white grubs, 20 c. c. water (ext. 6 hrs. old)............................	CS_2, nearly saturated................	24½ hrs.....	0.6 c. c....	0.5 c. c....	3.9 c. c....	0.9 c. c.
	Totals........................	....	....	6.7 c. c....	....	19.1 c. c....	....
5.	1 large and 6 small white grubs, 18 c. c. water............................	Gasoline vapor, low concentration.....	6 hrs.......	1.9 c. c....	1.3 c. c....	1.8 c. c....	1.3 c. c.
6.	8 *Allorhina* grubs, 20 c. c. water.........	Gasoline vapor, high concentration....	16 hrs......	2.5 c. c....	2.0 c. c....	4.5 c. c....	4.0 c. c.
7.	6 *Allorhina* grubs, 20 c. c. water.........	Gasoline vapor about ⅔ concentration..	17 hrs......	2.1 c. c....	2.8 c. c....	3.3 c. c....	2.3 c. c.
8.	6 large *Allorhina* grubs, 20 c. c. water....	Gasoline vapor, low concentration.....	4 hrs.......	1.2 c. c....	0.8 c. c....	1.1 c. c....	0.7 c. c.
9.	8 *Passalus cornutus*, 30 c. c. water.......	Gasoline treated.....................	8½ hrs......	0.6 c. c....	1.0 c. c....	1.6 c. c....	0.4 c. c.
10.	8 *Passalus cornutus*, 30 c. c. water.......	Gasoline treated, but no insecticide present during the experiment.......	16 hrs......	1.9 c. c....	0.5 c. c....	1.6 c. c....	0.6 c. c.
	Totals........................	....	....	10.2 c. c...	....	13.9 c. c...	....
				Check extract — no hydroquinone.		Extract plus hydroquinone.	
				O_2 used.	CO_2 given off.	O_2 used.	CO_2 given off.
11.	5 *Passalus cornutus*, 20 c. c. water.......	No insecticide used..................	2¼ hrs......	0.7 c. c....	0.4 c. c....	0.9 c. c....	0.3 c. c.
12.	4 *Passalus cornutus*, 15 c. c. water.......	No insecticide used..................	15 hrs......	0.7 c. c....	0.4 c. c....	3.4 c. c....	1.0 c. c.
13.	4 *Passalus cornutus*, 10 c. c. water.......	No insecticide used..................	6 hrs.......	2.0 c. c....	0.4 c. c....	4.4 c. c....	0.9 c. c.
	Totals........................	....	....	3.4 c. c....	....	8.7 c. c....	....

extracts (before samples for the tests were taken) four drops of weak ammonia (0.9 sp. gr. diluted five times) were added. This ammonia had the effect to reduce the carbon dioxide excreted to a very small amount.* The influence of oxidase in causing the hydroquinone to take up oxygen in the manner described might therefore stand out prominently. The total oxygen taken up and the total carbon dioxide given off in each case is given in the table, and although the ammonia used kept the ratio $\left(\frac{CO_2}{O_2}=\frac{1.2}{3.4}\right)$ down to 0.35 in the extract containing no hydroquinone, the value was brought down lower still $\left(\frac{CO_2}{O_2}=\frac{2.2}{8.7}\right)$ to 0.25 by the increased amount of oxygen used in the extract plus hydroquinone mixture. The larger value of the ratio $\frac{CO_2}{O_2}=0.8$, as found above for the "extract plus hydroquinone" in the insecticide chamber, must therefore point to the fact that the gasoline and carbon disulphide vapors used were able in some unknown manner to inhibit or lessen the accelerating (catalytic) action of the extract-oxydase in bringing about the oxidation of hydroquinone. A further precaution which was observed should be explained here. Tissue-extract was brought to a boiling temperature (about 15 to 20 minutes) to destroy the oxidasic enzymes. It was then allowed to cool and the regular amount of hydroquinone solution was added. Tests were then made using the apparatus as in other experiments, and no measurable amount of oxygen was taken up during longer periods than any used in the regular experiments. It has already been explained that the hydroquinone stock solution would remain clear for days. However, if the heated "extract plus hydroquinone mixture" had been scarcely brought to the boiling temperature or had been heated only a short time before it was allowed to cool, it often showed a very slight reddish or cherry tinge after twenty-four to thirty hours—indicating that the heat had not been sufficient to destroy quite all of the oxidasic activity. Thus, the appearance of this peculiar reddish brown color was an even more delicate test of the oxidation of hydroquinone than the volumetric measurement of the oxygen used, and mention has already been made of how the reddish brown tinge deepened progressively as hydroquinone became oxidized to quinone. It was interesting and confirmatory, therefore, to note that in all ten of the experiments listed in table II the deeper color was found to be in the stender dish of that gas container where most oxygen had been taken up. One must see that in the extracts used, a slight respiratory exchange exists, and the influence of the insecticide agents upon this exchange has not been eliminated; but the respiratory exchange in such a treated extract (a few hours old) is very low indeed as shown by the CO_2 given off—and the evidence just enumerated leaves no doubt that in studying the comparable oxygen measurements, we see mainly the influence of the agents in question upon the oxidase activity toward hydroquinone. Two experiments (not recorded in table II), carried at once for short periods with gasoline vapor in high concentration, gave results contradictory to all the rest as far as gas measurements were concerned—that is, the measurements seemed to show that most oxygen had been taken up in the gasoline-treated chamber. Nevertheless, when run for longer periods afterward, the "extract plus hydroquinone" mixture in the gasoline chamber showed a reddish brown color not nearly so deep as that in the check gas-chamber containing air only, and the volumetric results then agreed with the results of the other experiments. The reason for the apparently contradictory results of the first and second parts of these two experiments was not understood until later. About a year and a half after these first experiments had been made (i. e. after the effect of gasoline upon the tissue reductase had been studied) it was decided to run a few more tests with gasoline-vapor, using a different method, in order to find out more surely if possible, the influence of this insecticide upon the absorption activity for oxygen of "insect tissue-extract plus hydroquinone" solution. The method decided upon was the old one (described in Part 1, Tech. Bull. II) in which the percentages of the gases present were determined at the beginning and at the end of the test period; but a different arrangement of gas-containers and gas- burettes was made to adapt the method to this problem.

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*See effect of ammonia on $\left(\frac{CO_2}{O_2}\right)$. Tech. Bulletin 11.

The arrangement of containers and burettes in the apparatus used is represented in Fig. III. As may be seen, the apparatus is an adaptation of that shown in Fig. 1, with the circulating pumps and absorption flasks left out. There were two duplicate systems—gasoline-vapor-air was used in the gas-chamber of one system and pure air in the other. Hydroquinone burettes enabled one to introduce the hydroquinone as described in the case of apparatus Fig. I. The two gas-containers had each two two-way cocks, and these enabled one to adjust the mercury manometers and to take gas samples for estimation from each container at the beginning and at the end of test-periods. The gas-burettes permitted one to keep close check upon changes in gas-volume in each system, the readings being made at the known temperature and barometric pressure. From the percentage determinations (since the cubic contents of each system was known) one could figure the amount of oxygen used and of carbon dioxide given off at 760 m. m. pressure and O°C., as well as the exact percentage of gasoline to which the "insect-extract plus hydroquinone" solution had been subjected in the test. A set of results obtained with this arrangement of apparatus is given in table III. The total oxygen absorbed in the pure air chamber exceeded the total oxygen absorbed in the gasoline-air chamber, and the ratio $\frac{CO_2}{O_2}$ was a little higher in the gasoline-air chamber. By this method, as with the former method, however, it was found that if fresh extract were used for a short period, the result might be contradictory to that given for a much longer or for a later period with the same extract.

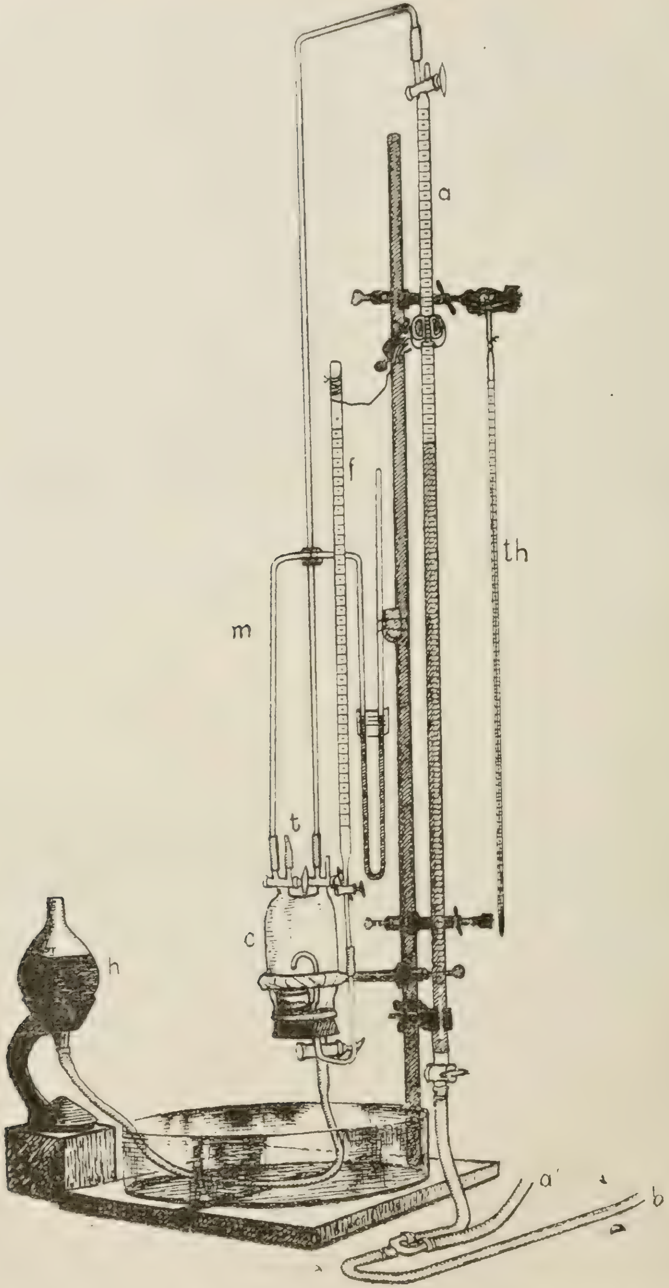

Fig. III. Shows half of a duplicate gas apparatus used for studying the influence of various agencies on certain activities of insects and insect tissue extracts: a = gas burette; b = rubber tube connected with mercury mug; a' = tube leading to duplicate gas burette; f = burette for hydroquinone solution or hydrogen peroxide or etc.; m = tube connecting gas container "c" with a mercury manometer; th.= thermometer; t = outlet of gas-cock.

TABLE III.—EFFECT OF GASOLINE VAPOR ON THE AMOUNT OF OXYGEN ABSORBED BY INSECT TISSUE-EXTRACT PLUS HYDROQUINONE-SOLUTION.

(Method of percentage estimations).

Exp. No.	Stock extract from:—	Gasoline vapor.	Period.	Insecticide chamber.		Check gas chamber.		Remarks.
				O_2.	CO_2.	O_2.	CO_2.	
1.	8 *P. cornutus*, 20 c. c. water	4.6%	16½ hrs.	2.2 c. c.	0.6 c. c.	2.8 c. c.	0.1 c. c.	0.6 c. c. more O_2 absorbed in the air chamber.
2.	a. 9 *P. cornutus*, 15 c. c. water	4.37%	5 hrs.	2.69 c. c.	0.2 c. c.	1.7 c. c.	0.4 c. c.	0.9 +c. c. more O_2 used in the gasoline chamber.
	b. 9 *P. cornutus*, 15 c. c. water		19 hrs.	2.3 c. c.	0.96 c. c.	2.72 c. c.	0.5 c. c.	0.4 +c. c. more O_2 used in the air chamber.
3.	9 *P. cornutus*, 15 c. c. water	6.7%	17 hrs.	2.7 c. c.	0.4 c. c.	2.9 c. c.	0.5 c. c.	0.2 c. c. more O_2 used in the air chamber.
4.	a. 15 *P. cornutus*, 22 c. c. water	6.96%	6 hrs.	1.31 c. c.	0.9 c. c.	1.73 c. c.	0.39 c. c.	0.42 c. c. more O_2 used in pure air.
	b. 15 *P. cornutus*, 22 c. c. water		14½ hrs.	0.72 c. c.	0.0 c. c.	1.6 c. c.	0.9 c. c.	0.88 c. c. more O_2 used in the pure air.
5.	15 *P. cornutus*, 22 c. c. water	5.9%	17 hrs.	1.1 c. c.	0.72 c. c.	1.6 c. c.	0.52 c. c.	0.5 c. c. more O_2 used in pure air.
	Totals			13.02 c.c.	3.78 c. c.	15.05 c.c.	3.31 c. c.	
	Totals, leaving out No. 2, a			10.33 c.c.	3.58 c. c.	13.35 c.c.	2.91 c. c.	

This is illustrated in table III by No. 2, where in the first five hours, the fresh extract used 0.9 c. c. more O_2 in the gasoline chamber than was used by its duplicate sample in pure air. When the same samples had then run undisturbed for nineteen hours, it was found on the other hand, that the pure air sample had taken up the most oxygen by 0.4 c. c. In No. 4 the stock extract was about five hours old when the samples were taken for the tests. Note that in this case, while the first test period of six hours showed more oxygen used in pure air, the longer second period gave an increased excess of oxygen used by the pure air sample. These results, taken with those obtained by the former method, seem to justify the conclusion that carbon disulphide and gasoline inhibit or lessen the rate of oxidation of hydroquinone in solution in the tissue extract of *Passalus cornutus.* Furthermore, in the case of gasoline, the effects on the rate of oxidation are not marked, unless the extract is a few hours old at the beginning of the test; and if perfectly fresh extract is used for a short period the results may be contradictory—apparently. As has already been mentioned, however, the series of experiments, results of which are recorded in Table III, were run after a study had been made of insect tissue reductase and of the effect of gasoline upon the reductase. This latter study, it is believed, affords an explanation of the apparantely contradictory results obtained when gasoline-vapor acts for short intervals upon freshly made "insect-tissue extract plus hydroquinone" solution. (See page 28.)

(b) INFLUENCE UPON THE REDUCING ACTIVITY.

Some evidence has already been given of the existence of a strong reducing power in the fresh extract of *Passalus cornutus;* namely, the reduction (when air is excluded) of the dark melanic pigment which develops in the extract through the influence of the oxidasic enzymes when tissue-extract has been exposed to the air for a while, and the reduction of methylene blue to leuco-methylene blue when air is excluded from extract to which a little methylene blue has been added. Still other evidence may be given. If comparatively fresh "extract plus hydroquinone" which has already oxidized enough of the hydroquinone to quinone to give the solution a reddish-brown hue, is then confined in the absence of air or free oxygen for a few hours, the reddish-brown quinone will all be reduced; and if a little perfectly fresh extract is added before excluding the air, the reduction takes place more rapidly. Fresh extract stained blue with a little indigo carmine will reduce the stain to leuco-indigo carmine in the absence of free oxygen; and then, the reduced color body will oxidize and turn the extract solution blue again, if air is admitted—just as happens also when confined extract, holding leuco-methylene blue, is once more exposed to the air. After fresh extract has caused alcoholic guaiac to be oxidized to guaiac blue, if the entire mixture is then confined from free oxygen, the reducing bodies show their presence by reducing all guaiac-blue back to its former condition. Likewise, after tyrosin has been oxidized to the black melanic pigment, the latter can then be reduced by the extract, if air is excluded. In every case after reduction, oxidation may again be brought about if the confined extract containing the reduced body is once more exposed to air.

It should be explained here, perhaps, that the strength and persistence of the reduction-activity varied a little with different lots of beetles, and that it always seemed to be best in the case of beetles showing the greatest strength and vitality.

Before discussing the effect of temperature, gasoline and other agencies upon the reductase, it will be best to describe briefly the method used in confining insect tissue-extract in the absence of air so that a study of its reductase activity under the influence of the various agents and conditions could be carried on in a manner which would permit of comparisons being made. As a rule, it was necessary to use small amounts of the extract and a method was needed by which the air could be excluded as completely as possible—and excluded quickly. After various means had been tried, the following plan was found to serve well. Small glass tubes of the same diameter and of practically the same length were heated and drawn out at each end to a fine capillary bore. The extract to be studied could be quickly drawn up to fill a tube, and then the capillary ends could be sealed at once by touching them in a hot gas flame. Fig. 2, Plate I, is a photograph of such a sealed tube. Methylene blue was the "substrate and indicator" most often used in making a study of the reduction activity. A standard solution of 0.1 gram of methylene blue in 100 c. c. of distilled water was employed. Unless otherwise stated in giving the results, six drops of this standard solution from the methylene blue pipette were used to 4 c. c. of the extract. (In most cases this ratio was found to be best.) The stain was thoroughly mixed with the extract and then the extract was divided into two equal parts—the one part to be treated for a certain time with the insecticide and the other, held as a check. Or, if two equal portions of the extract were taken at first, an equal number of drops of the standard methylene blue was added to each from a graduated pipette at practically the same time. At the end of the treatment period both parts were again shaken until they became a uniform blue. Then, from the treated and untreated stained extracts, tubes were quickly drawn full and sealed. Note was made of the period of time required for each tube to become reduced entirely free of the blue color. The time intervals given by this method for tubes of treated and untreated extract thus furnished the means for an instructive study of the influence of insecticides (or temperature, etc.) upon the reductase activity of any extract. Methylene blue showed a very slight deteriorating influence upon the reductase, it was found, but in the method this is not to be regarded since the stain was added to the treated (with insecticide) and the untreated portions of the extract at the same time in equal amounts as explained—all other conditions being the same for both portions of the extract, except the one condition under consideration.

By this method the influence of temperature, chloroform, ether, alcohol, gasoline, formaldehyde, carbon disulphide, hydrocyanic acid gas, toluol, ammonium formate, sodium fluoride, borax, mercuric chloride, pyrethrum, to-bak-ine and white hellebore was studied. Representative results are given in Table IV where the ratio between the time required to reduce methylene blue in the check and the time requird in the case of the treated extract may easily be obtained.

TABLE IV.—INFLUENCE OF CERTAIN INSECTICIDE AGENTS ON THE REDUCING ACTIVITY (ON METHYLENE BLUE) OF EXTRACT FROM THE TISSUES OF *PASSALUS CORNUTUS*.

(Solution of Meth. Blue =0.1 gram in 100 c.c. of dist. water.)

Exp. No.	Agent.	Time extract was treated before being drawn into tube and sealed.	Time required to reduce Methylene Blue in the treated extract.	Time required to reduce Methylene Blue in the check extract.
1.	Gasoline, 0.5 c.c. to 4 c.c. of the extract	10 min	35 min	7 min.
2.	Gasoline, 1.0 c.c. in 3 c.c. of the extract	3 min	17 hrs	14 min.
3.	Carbon disulphide, 0.5 c.c. in 3 c.c. of extract	3 min	1 hr., 16 min.	14 min.
4.	Carbon disulphide, 0.5 c.c. in 3 c.c. of extract	23 min	3 hrs., 21 min.	19 min.
5.	Alcohol, 0.5 c.c. to 2 c.c. of extract	5 min	6 min	1½ min.
6.	Alcohol, 0.5 c.c. to 2 c.c. of extract	15 min	10 min	2 min.
7.	Chloroform, 0.5 c.c. to 2 c.c. of extract	5 min	48 min	8 min.
8.	Ether vapor, saturated	35 min	5 min	7 min.
9.	Ether, 0.5 c.c. in contact with 2 c.c. of the extract	5 min	17 min	9 min.
10.	Formaldehyde (40%) 3 drops in 2 c.c. of extract	5 min	Still quite blue after 24 hrs.	10 min.
11.	Tobakine, 1 drop to 2 c.c. of extract	5 min	10 min	10 min.
12.	HCN., (from KCN and H_2SO_4) strong charge 10 min. [aired 20 min.]	10 min	30 min	4 min.
13.	Treated in a very strong Cyanide bottle, 2 hrs. (aired 5 min.)	2 hrs	1 hr., 50 min.	55 min.
14.	Beetles treated for 15 hrs. in Cyanide bottle, and then aired ½ hr. before extraction		18 min	4 min.
15.	Toluol, 3 drops to 2 c.c. of extract	4 min	5½ min	2½ min.
16.	Toluol (same as above)	15 min	30 min	15 min.
17.	Pyrethrum, 0.5 c.c. dry powder to 2 c.c. of extract	5 min	4 min	1½ min.
18.	Pyrethrum (same as above)	27 min	38 min	6 min.
19.	Pyrethrum (same as above)	2 hrs	18 hrs	1 hr., 25 min.
20.	White Hellebore, 0.5 c.c. dry powder to 2 c.c. extract	5 min	4½ min	3 min.
21.	White Hellebore (same as above)	10 min	16½ min	5 min.
22.	White Hellebore (same as above)	97 min	Between 16 and 18 hrs.	1 hr., 40 min.
23.	$HgCl_2$, 1 drop of saturated solution in 2 c.c. of extract	5 min	No apparent reduction at all	20 min.
24.	NaF (sat. solution), 1 c.c. to 3 c.c. of extract; 5 drops of Meth. Blue	8 min	6 min	3 min.
25.	NaF (sat. solution), 1 c.c. to 3 c.c. of extract; 5 drops of Meth. Blue	25 min	8 min	10 min.
26.	NaF (sat. solution), 1 c.c. to 3 c.c. of extract; 5 drops of Meth. Blue	65 min	21 min	1 hr., 50 min.
27.	Borax (3 grms. in 100 c.c. water), 0.6 c.c. to 2 c.c. of extract	10 min	27 min	10 min.
28.	Borax (3 grms in 100 c.c. water), 0.6 c.c. to 2 c.c. of extract	30 min	1 hr., 50 min	46 min.
29.	Am. Formate, 1 c.c. of $\frac{M}{1000}$ solution to 2 c.c. of extract	5 min	15 min	5 min.
30.	Temperature 58° C	5 min	About 10 hrs.	2 hrs.
31.	Temperature 0° F. for 3 hrs		After first warming, 3½ min.	Average of fresh extract, 1½ min.
32.	Temperature 70° F. stood for 3 hrs		6 hrs	1 min.
33.	Carbon tetrachloride, 4 drops in 4 c.c. of extract	15 min	70 min	18 min.
34.	Air saturated with vapor of carbon tetrachloride at 70° F	40 min	3¼ hrs	1¼ hrs.

The results as given here are designed only to show whether the influence of the agent upon the reducing power of the extract is marked or not. The reducing activity of the tissue extract of *P. Cornutus* may be entirely destroyed by a continuous temperature of 100° C. for ten to fifteen minutes. While this high continuous temperature is necessary for *complete* destruction, the greater part of the activity is quickly lost at 58° to 60° C. A low temperature tends to conserve the reducing activity—indeed, it serves, at once, to conserve and to inhibit the reducing power of the extract. No. 31 of Table IV gives a trial with extract kept for three hours at 0° F. When this extract was quickly but gently warmed to room temperature, it reduced methylene blue in 3½ minutes, whereas extract that had stood exposed to the air at 70° for three hours required six hours to reduce the color. The checks of fresh extract at the beginning reduced the same amount of methylene blue in one minute and in 1½ minutes. The reducing activity of fresh extract seems to be best at a room temperature of about 70° to 80° F., but it rapidly deteriorates during the first five to six hours after extraction (at the room temperature) and gradually, more slowly afterward. This is true even when the fresh extract is confined from the air. For example, a certain check of perfectly fresh extract reduced its methylene blue more than six times faster than another portion of the extract (A) which was tested after its confinement from air for 1½ hours from the moment of its extraction. Nevertheless "A" was 2½ times faster in reducing its methylene blue than a third portion (B) of the same extract which had been exposed to the air during the 1½ hour period. One might think from this that confinement from air tended to conserve the reducing activity. It is necessary to remember, however, that a dark melanic pigment developed in any extract (as "B") exposed to the air, due to the influence of the oxydase present, and that a portion (as A) confined from air could develop no pigment. When "A" and "B" were finally given the reduction-test with methylene blue, then (at the end of 1½ hours in this example), the reductase in "A" had only methylene blue to reduce while that in "B" attacked the dark pigment as well as the methylene blue. It seems likely, therefore, that the longer time for the reduction of the methylene blue was required by "B" because of the greater work in reducing the melanic pigment in addition to the methylene blue, rather than because its reducing activity had become less than that in "A".

Mention has already been made of the fact that when fresh extract is exposed to the air, it darkens first, only in a thin film at the surface. Also, if the fresh extract is allowed to stand after it has been stained with methylene blue and shaken so that the color is uniform throughout, it will be but a few minutes until the surface only will be blue—a reduction of all color in the deeper portions of the container having taken place. After a time, however, the blue coloration will begin—slowly at first and then more and more rapidly—to extend deeper into the container; in the case of the unstained extract, the dark melanic pigment will gradually form more rapidly as time goes on. It was soon found that this increased rapidity in the reoxidation of the methylene blue and in the formation of the melanic pigment coincided or tallied with the deterioration in the activity of the reductase of the extract on standing. That is to say, when the extract was new and its reductase still remained strong, it visibly held in check the work of the oxydase in the same extract. This proved as well to be the case when alcoholic guaiac or hydroquinone solution was used in the extract as the agent to be oxidized. Now, as may be seen by Nos. 1 and 2 of Table IV, gasoline was found to be quickly and strongly deleterious to the reducing activity of fresh extract of *Passalus cornutus*. The influence of strong gasoline-vapor upon the reductase was decided and much more marked than any influence upon the oxidase-activity—furthermore, the resultant-effect of gasoline-vapor upon the oxidasic action in very fresh extract was plainly due, in part, to the deleterious effect upon the reductase, since the latter was an inhibitor of the oxidasic processes. It was evident that in nearly elminating the reductase activity in the treated portion of a *fresh* extract, gasoline-vapor removed at once a greater inhibiting influence upon oxidasic action than it could itself exert—while in the check portion of the extract this inhibiting influence of the reductase continued for a few hours until it gradually disappeared through standing. Hence, a short period test of oxidase activity was sure to show that most oxygen had been taken up by the gasoline treated portion of a *fresh* extract. On the other hand, when the test with gasoline-vapor was made with extract that was a few hours old before the test began (and had thus already lost its strong reduction-activity) the inhibiting influence of the gasoline-vapor upon oxygen absorption in the "extract plus hydroquinone" solution became readily apparent in either long or short period tests. Thus, an explanation was afforded of those apparently contradictory results obtained when studying the action of gasoline-vapor upon hydroquinone-oxidase activity.

Table IV hardly shows the true extent of the deleterious effect of carbon disulphide upon the reduction-activity of fresh extract—since, in making check studies, it was found that methylene blue was slowly reduced by carbon disulphide alone, in the absence of air. However, that insecticide had little or no effect on indigo carmine, and when the latter was used as the test agent (½ grm. in 100 c. c. dist. water), it appeared that carbon disulphide was much more decidedly harmful to the reduction-activity of the extract than the study with methylene blue would lead one to believe.

It will be noticed from the table also that the amount of ether-vapor taken up by a water extract seemed to slightly increase or stimulate the reduction activity—whereas a small amount of liquid ether shaken up in the extract brought about noticeable deterioration in the reduction power. On the other hand, immediately upon being added in small amounts, a slight drop in the reduction-activity was caused by sodium fluoride, but after that it tended very markedly to preserve the reducing power of an extract (Nos. 24, 25 and 26 of Table IV).

The table (IV) itself, perhaps, gives sufficient explanation of the results for the remainder of the agents tested in this connection.

(c) EFFECT UPON THE CATALASES.

Brief mention has already been made of the presence of soluble and insoluble catalases in the tissue-extract of *Passalus cornutus*. Loew found that the alpha (i. e. insoluble) catalase of tobacco was slightly soluble in water after a time, and this appears to be true of the corresponding catalase in the insect tissue extract. The soluble and insoluble catalases seem to be affected alike by heat and other agents, except that the insoluble form is a little more resistant in most cases. The tissue-pulp or crude water extract of *P. cornutus* may be dried without destroying the ability to liberate oxygen from hydrogen peroxide, but long continued drying injures that ability. A temperature of 59° C. for 10 minutes is sufficient, usually, to destroy almost all the catalase activity in the pulp or crude water-extract from this beetle, leaving the oxydasic power of the same pulp or extract still very active toward guaiac or tyrosin. Sometimes an extract was found to show a little greater resistance to heat; and in any case, if one wished to be sure of destroying absolutely all catalase activity toward hydrogen peroxide, so that small bubbles of oxygen would not appear even after several hours, a temperature very near the boiling point was required. It was possible to separate the soluble catalase from its solution but not to free it from proteins. The catalase was carried down with the protein precipitate by either half or full saturation with ammonium sulphate or with the precipitate by alcohol; and the precipitate from *full saturation* with ammonium sulphate was found to contain practically all of the catalase.

In making a quantitative study of the influence of insecticide agents on the catalases one could obtain a little more uniformly constant results by using a fairly clear solution in which any insoluble particles present would be extremely fine, so that they would remain in suspension for hours. The results given in Table V are therefore taken from a study of the influence of certain agents upon the catalases in such an extract solution from the tissues of *P. cornutus*. The beetles were extracted in the usual way (i. e. digestive tract removed, etc.), using distilled water at the rate of about 12 c. c. to 5 beetles. The crude extract was filtered through linen of very fine mesh. Two cubic centimeters of this filtrate were then measured out and diluted to 10 c. c. with distilled water. In this way an almost clear dilution was obtained in which the fine particles remained in suspension for hours; and by agitating the dilution just before dividing it, one could obtain entirely uniform samples. In every test, 2 c. c. of this diluted extract were measured out into a small stender dish and submitted to the treatment under consideration for the required time. A check of 2 c. c. was also measured out. In some cases where gases or vapors were used, the stender dish with treated extract was allowed to air for a certain period before the final test with hydrogen peroxide was made. For measuring the amount of oxygen liberated from hydrogen peroxide by the treated portion of the extract and by the check, the apparatus represented in Fig. III was used. As has already been explained, this apparatus was in duplicate so that the test with the treated extract could be run in one and the check in the other duplicate. After the stender dish of extract had been introduced into the gas-container. mercury seal was made at the mouth of the container. The mercury manometer was adjusted level, and the reading of the gas-burette taken. Then 5 c. c. of hydrogen peroxide were drawn in form burette "f". As oxygen was liberated and the volume of the gas in the container increased, the mercury in the gas-burette was lowered until the manometer was once more level just at the end of 10 minutes. Then the reading of the gas-burette was again taken. The increase in volume less 5 c. c. (i. e. 5 c. c. of H_2O_2), represented, the oxygen liberated. Any variation in the volume of oxygen liberated by the treated extract from the volume liberated by the check, therefore, was due to the influence of the treating agent, since all the other conditions were the same for both extracts. After an extract was

TABLE V.—INFLUENCE OF INSECTICIDE AGENTS ON THE CATALASES FROM TISSUES OF *P. CORNUTUS*.

Exp. No.	Agent.	Time agent was used.	After treatment.	O_2 liberated from H_2O_2 by treated ext. in 10 min. period.	O_2 liberated from H_2O_2 by check in 10 min. period.	Ratio of treated to untreated.
1.	Strong Cyanide bottle	17 hrs	Aired 5 min	5.5 c. c.	55.0 c. c.	0.1
2.	Strong Cyanide bottle	Same 17 hrs	Aired 2 hrs	17 c. c.		0.3
3.	Strong Cyanide bottle	Same 17 hrs	Aired 8 hrs	26.2 c. c.	55.0 c. c.	0.47
4.	CS_2 (Air—Sat. vapor)	2 hrs	15 min	2.0 c. c.	55.0 c. c.	0.03
5.	CS_2 (Air—Sat. vapor)	Same 2 hrs	16 hrs	1.0 c. c.	55.0 c. c.	0.01
6.	Air sat. with gasoline vapor, 4½%	1 hr		40.0 c. c.	38.0 c. c.	1.05
7.	Air sat. with gasoline vapor, 4½%	16 hrs		36.0 c. c.	36.0 c. c.	1.0
8.	Carbon tetra-chloride vapor. Sat. air	16 hrs	Aired 10 min	56.5 c. c.	62.0 c. c.	0.92
9.	Carbon tetra-chloride vapor. Sat. air	Same 16 hrs	Aired 1½ hrs	57.5 c. c.	62.0 c. c.	0.94
10.	Chloroform vapor (air sat. at 68° F.)	16 hrs	Aired 5 min	40.5 c. c.	50.0 c. c.	0.81
11.	Chloroform vapor (air sat. at 68° F.)	Same 16 hrs	Aired 5 hrs	41.5 c. c.	50.0 c. c.	0.83
12.	Ether vap. air sat. at 68° F	¾ hr	20 min. airing.	60.5 c. c.	60.0 c. c.	1.0
13.	Ether, 0.5 c. c. shaken up with 2 c. c. of ext	15 min	Aired 2 hrs. until ether was evaporated	58.0 c. c.	59.0 c. c.	0.98
14.	Ammonia (0.9 sp. gr. —2 c. c. diluted to 100 c. c.) 0.5 c. c. of dilution to 2 c. c. of ext	5 min		47.2 c. c.	56 c. c.	0.84
15.	Am. vap. (100 c. c. air sat'd. from 5 c. c. am.—water of 0.9 sp. gr.)	1 hr	Aired 30 min	0.5 c. c.	56 c. c.	0.008
16.	Tobakine, 1 drop to 2 c. c. of ext	10 min		65.0 c. c.	63.5 c. c.	1.02
17.	Tobakine, 1 drop to 2 c. c. of ext	¼ hr		54 0 c. c.	61.0 c. c.	0.88
18.	Alcohol abs., .05 c. c. to 2 c. c. of ext	10 min		50.0 c. c.	49.0 c. c.	1.02
19.	Alcohol abs., .05 c. c. to 2 c. c. of ext	60 min		48.0 c. c.	53.5 c. c.	0.89
20.	Alcohol abs., 1 c. c. to 2 c. c. of ext	45 min		4.8 c. c.	53.5 c. c.	0.089
21.	$HgCl_2$, 1 drop of sat. sol. to 2 c. c. of ext	5 min		No measurable amount	54.4 c. c.	
22.	1 c. c. of N/100 HCl to 2 c. c. of ext	10 min		2.5 c. c.	54.0 c. c.	0.04
23.	Same treatment as No. 22	Kept cold 19 hrs		0.8 c. c.	54.0 c. c.	0.01
24.	NaOH 0.2 c. c. N/100 to 2 c. c. of ext	3½ hrs		35.5 c. c.	32.5 c. c.	1.09
25.	Am. Formate (M/1000) 1 c. c. with 2 c. c. of ext	20 min		32.0 c. c.	61.0 c. c.	0.52
26.	Am. Formate (M/1000) 1 c. c. with 2 c. c. of ext	55 min		31.0 c. c.	61.0 c. c.	0.50
27.	Formaldehyde 0.3 c. c. of 40% to 2 c. c. of ext	15 min		0.5 c. c.	41.0 c. c.	0.01
28.	Heat 52° C	5 min		47.0 c. c.	54.0 c. c.	0.87
29.	Heat 56° C	5 min		13.0 c. c.	54.0 c. c.	0.24
30.	Heat 59° C	2 min		11.0 c. c.	61.4 c. c.	0.17
31.	Heat 59° C	10 min		Amt. scarcely measurable	61.4 c. c.	
32.	Pyrethrum powder, 0.5 c. c. by measure to 2 c. c. of ext	40 min		23 c. c.	51.0 c. c.	0.45
33.	White Hellebore, 0.5 c. c. powder to 2 c. c. of ext	5 min		57 c. c.	55.5 c. c.	1.02
34.	White Hellebore, 0.5 c. c. powder to 2 c. c. of ext	30 min		53 5 c. c.	55.5 c. c.	0.96

TABLE V.—CONCLUDED.—INFLUENCE OF INSECTICIDE AGENTS ON THE CATALASES FROM TISSUES OF *P. CORNUTUS*.

Exp. No.	Agent.	Time agent was used.	After treatment.	O_2 liberated from H_2O_2 by treated ext. in 10 min. period.	O_2 liberated from H_2O_2 by check in 10 min. period.	Ratio of treated to untreated.
35.	Borax (3 grms. in 100 c. c. water) 0.5 c. c. to 2 c. c. ext	Used 20 min. before testing		49.0 c. c.	55.0 c. c.	0.89
36.	Borax (3 grms. in 100 c. c. water) 0.5 c. c. to 2 c. c. ext	½ hr.		60.5 c. c.	61.4 c. c.	0.96
37.	NaF, 0.5 c. c. sat. sol. to 2 c. c. of ext	15 min.		11.7 c. c.	60.4 c. c.	0.19
38.	NaF, 0.5 c. c. sat. sol. to 2 c. c. of ext	45 min.		12.0 c. c.	56.0 c. c.	0.21

a few hours old (i. e. after the reductase had become weak) there was little change in the catalase activity during the next 24 hours (or even 48 hours if the extract were kept covered at near freezing). On this account, it was not always necessary to run a check for each test in a series when treated extract-samples from the same dilution were used. Instead, a check could be made at the beginning of the series and another check held until the end. If a perfectly fresh extract were used, however, the checks had to be run more often, because the strong reductase present inhibited the catalase a little; and as the former weakened on standing, the catalase was able to liberate more oxygen in a ten-minute period. For example, in one extreme case, 2 c. c. of a fresh extract dilution gave (with 5 c. c. of hydrogen peroxide) in 10 minutes, 54.5 c. c. of oxygen, while 2 c. c. of the same dilution kept at 40° F. over night liberated 61 c. c. of oxygen in 10 minutes. In another case using the same method, 2 c. c. of a fresh extract-dilution liberated 32 c. c. of oxygen while its check 3 hours later (at room temperature) liberated 34 c. c. of oxygen. It should be added that *after* this rise due to the passing of the reductase activity, the ability to liberate oxygen from hydrogen peroxide gradually diminished during longer periods of time.

About 75 quantitative tests were carried out by the methods described above to determine the effects of certain insecticide agents upon catalase activity. Representative results of these tests are recorded in Table V.

In discussing the influence of hydrocyanic acid gas on the oxidasic activity of the insect tissue-extract toward alcoholic guaiac, it was stated that, when the test was made immediately after treatment, the guaiac turned blue very much more slowly than in the check. On the other hand when the treated extract was allowed to stand in the air for a while, the influence of the cyanide gas gradually passed off until the treated extract would oxidize the guaiac almost as rapidly as the check. In other words, there was a partial progressive recovery. Table V shows that this insecticide agent behaved in the same manner toward the hydrogen peroxide catalases. In the experiment, results of which are given in the table, a little more than 6 c. c. of extract was kept in a strong cyanide bottle for 17 hours. At the end of that time, it was removed to the open air. After airing only 5 minutes, a test was made with 5 c. c. of hydrogen peroxide and in the following ten-minute period 2 c. c. of this extract liberated only 5.5 c. c. of oxygen—the check, in the same time, liberated 55 c. c. of oxygen. After airing for 2 hours, 2 c. c. of the same treated extract liberated 17 c. c. of oxygen; and after standing in the air for 8 hours until almost all odor of the cyanide gas had disappeared, 2 c. c. of the treated extract caused 26.2 c. c. of oxygen to separate from the 5 c. c. of hydrogen peroxide in a ten-minute period —the check giving 55 c. c. of oxygen. Other tests gave similar results, so that there is no doubt of a partial, progressive recovery of the catalase activity toward hydrogen peroxide in an extract treated with cyanide gas upon standing in the open air. Furthermore, the results of these tests seemed to show that both the soluble and insoluble catalases in the dilute extract had been affected and that both had recovered the greater part of their activity after the passing of the poison. In order to make more certain that this was the case, a few experiments were tried in which hydrocyanic acid gas (from KNC + dilute H_2SO_4) was made to act upon the two catalases separately. The crude extract was filtered. Then the clear filtrate, containing the soluble catalase, was diluted and treated by the method already described. The residue on the filter was washed as nearly free from the soluble catalase as possible, after which it was shaken up in a small amount of distilled water. This water containing the insoluble catalase in suspension was then divided into equal samples to be treated as in the other experiments. Charges of hydrocyanic acid gas sufficient to render specimens of *P. cornutus* helpless and quiet in 3 to 4 minutes were used. Such a charge of cyanide gas is much stronger than that used in ordinary fumigation. The charges were applied 40 to 45 minutes. (This was a longer time than was really necessary to kill specimens of the beetle.) The experiments showed that over 95% of the activity of the soluble catalase and only about 52% of the activity of the insoluble catalase was suspended at the end of a 45-minute period. There was 88% recovery, or more, (after the treated extract stood 15 hours at about 34° F.) in case of the soluble catalase, and about 21% recovery of the activity of the insoluble catalase toward hydrogen peroxide. The insoluble catalase seemed to show the greater resistance, but once its activity had been hindered by the poison, greater permanent injury resulted than in the similar event with soluble catalase.

A number of tests were made to determine whether any such recovery of the catalases in an extract would obtain, after treatment with hydrochloric acid instead of with hydrocyanic acid gas. In preparing a treated extract and its check for this test, when 1 c. c. of $\frac{N}{100}$ acid was added to 2 c. c. of extract, then 1 c. c. of distilled water of the same temperature as the acid was added to the 2 c. c. check extract in order to keep the same dilution in the two portions. The tests were run in the apparatus already described. Numbers 22 and 23 in Table V show that $\frac{N}{100}$ hydrochloric acid was quite destructive to the catalase; and there was no apparent recovery, even upon long standing, if the treated extract and its check were kept at a temperature not far above freezing during the long period of treatment. Upon standing after the first decrease in catalase activity, three cases of increased activity for liberating oxygen from hydrogen peroxide *did* occur in some of the early tests with hydrochloric acid. However, the increase in these three cases was really brought about by decay which (in a warm room) the weak acid used did not entirely prevent, for long, in the extract. With the precaution of keeping the extracts in the cold (near freezing) during the treatment period, no example of increase in catalase activity at any time after treatment with hydrochloric acid, up to 19 hours, was observed. It may be added that the deleterious action of this acid upon the reducing power of the extract was not so great as it was upon the catalase activity.

The series of tests, results of which are recorded in Table V to show the effect of heat upon the catalases, are for short-interval periods only. Other experiments showed that when the treatment-period was lengthened, temperatures yet lower than 52° C. showed appreciable injury to the catalase activity. For example, at a temperature ranging from 45° to 46° C. for two hours, the ratio of the volume of oxygen liberated in a test by the heat-treated extract to that liberated by its check was $\frac{75}{86} = 0.87$.

Some of the agents readily showed a slight acceleration of the catalase action, when used in small amounts. Attention may be called to gasoline and alcohol in the table (V) as illustrating this fact. The manner in which some of the insecticides (especially gasoline) appear to hasten oxidasic activity because of their deleterious action on the reducing power, when they were first applied to fresh extract, has already been described. It seems very likely that the slight acceleration of the catalase-action, at first, when an extract was treated with small amounts of the above insecticides, may have (in part at least) much the same explanation. That is, small amounts of gasoline, alcohol, and perhaps a few others, in attacking the reductases deleteriously before they attacked the catalases, removed a stronger inhibiting influence over the catalase than they themselves exerted, so that a resulting initial acceleration of the catalase action immediately followed. *Strong* treatment with the insecticides, however, so greatly hindered the catalase (as well as the reductase) activity, that there was a lessening of the volume of oxygen liberated from hydrogen peroxide. In the case of alcohol the deleterious effect of strong or more prolonged treatment was quite decided. Nos. 18 and 20 of Table V show that while 0.5 c. c. of absolute alcohol added to 2 c. c. of extract caused more oxygen to be liberated from hydrogen peroxide after a period of 10 minutes treatment, 1 c. c. of alcohol in 2 c. c. of extract for 45 minutes before the test brought the ratio of oxygen liberated by the treated to that liberated by the untreated extract down to 0.089. That is, the stronger treatment not only overcame the lead of the first increase, but reduced the catalase activity much below that of the check. The effect of strong, prolonged treatment with gasoline vapor was not so marked; it was sometimes barely able to overcome the first lead or increase in catalase activity—(the lead or increase which was due, as has already been suggested, to the removal of the inhibiting reductases). This is illustrated by the two experiments recorded in Table V, Nos. 6 and 7. In no case of strong treatment with gasoline vapor was the amount of oxygen liberated brought much below that of the check.

Ammonium formate and ammonium oxalate were used in the series of tests because they are known to be products formed when hydrocyanic acid gas breaks down in air. Ammonium formate, in any amount tried, permanently injured the catalytic action of the extract toward hydrogen peroxide, as illustrated in the table (V). Ammonium oxalate, on the other hand, served to slightly accelerate the liberation of oxygen from hydrogen peroxide by the catalases.

The influence of the other agents, so far as tested, are either made clear in the table or may be referred to later in discussing powdered solid contact insecticides.

DO THE CONTACT INSECTICIDES UNDER CONSIDERATION ACT UPON OXIDASES, CATALASES OR REDUCTASES IN THE LIVING TISSUES OF INSECTS TO CAUSE DEATH?

The experiments just described showed that the contact insecticides under consideration did interfere with the activity of the oxidases, catalases and reductases in the tissue extract of *P. cornutus*. In the concentrated form, such insecticides affected all three of the enzymes (if they may be so called) but usually not in the same degree. It was clear that carbon disulphide, for example, affected the oxidases and catalases more strongly than it affected the reductases—while gasoline, on the other hand, had its most deleterious influence upon the reductases.

Trial showed that oxidases, catalases, and reductases existed in the tissue-extract of many caterpillars, pupae and adult moths, as well as in the adults and grubs of various beetles. Also, reference has already been made to the work of Batelli and Stern* in relation to oxydones in insects. These authors, in the same year (1913), again described tyrosine-oxidase, polyphenol-oxidase, and oxydones in several forms of insects. Besides, a few other scattered references in literature briefly (often covertly) relate the occurrence of oxidases in the blood or in extracts from various lepidoptera, beetles and diptera. Loew has recorded the presence of catalase in three different beetles. In fact, the occurrence of oxidases, catalases and reductases in extracts appears to be as general among insects as among other forms of life.

Further experiments showed that extracts from tomato-worms did not give the test for oxidase with alcoholic guaiac but hydroquinone-oxidase and tyrosin-oxidase were clearly present as well as reductases and catalases. Moreover, the influence of gasoline and carbon disulphide upon the activity of extracts from white grubs (both *Lachnosterna* and *Allorhina*) and tomato worms was similar to that already recorded in connection with extracts from specimens of adult *P. cornutus*.

With these facts established, the question remained as to whether oxidases, catalases and reductases in the *living* tissues of *P. cornutus* became deleteriously affected by contact insecticides used in such amounts and for such periods only as were necessary to kill. That catalases and reductases, as found in the tissue extract of the insect, really existed in the living tissues (and were not after-products of the tissues in the extract) seemed reasonably certain. If hydrogen peroxide were introduced directly into the tissues in any part of the body of a living beetle, oxygen became liberated *at once* with great energy; and the reducing power of living animal tissues, generally, for methylene blue is well known. In technical bulletin 11 (this station), page 52 is reference to the fact that living beetles, in the absence of oxygen gas, reduced large amounts of indigo carmine and methylene blue which had been injected into the body tissues by means of a fine hypodermic needle. Even in the open air, a small amount of methylene blue, injected into the tissues of a beetle's body, became entirely reduced. When the reduced (leuco-) methylene blue was collected for excretion by the cells of the Malpighian tubules, however, it became oxidized to the blue color again in those cells. Still, this reoxidation of the color-body did not necessarily imply or prove the presence of oxidase activity, and no entirely satisfactory method of *visibly demonstrating* oxidase activity in the tissues of living uninjured insects was found. Upon studying the case, however, there was nevertheless found to be visible evidence of almost positive oxidase activity naturally present in certain living cells of most insects. The facts which set forth this evidence follow:—

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*Batelli and Stern (Biochem. Zeits., 1913, 56, 59-77). Rev., J. of the Chem. Soc., Vol. 103-104, part i, p. 1272.

The wing covers of newly emerged adults of *P. cornutus* were almost without color—pure white. They gradually began to brown, becoming darker and darker until they finally appeared jet black—and by that time, they were entirely dry and hard. When the dry, black wing covers were crushed and tested they were found to contain catalase and an (almost) insoluble tyrosin-oxidase (see Fig. 3, Plate I); reductase activity was practically absent. The dark coloring matter of the crushed wing-covers appeared to be identical with the dark pigment which formed when the insect-extract or blood was exposed to air. Moreover, this melanic pigment in both cases was like the melanic pigment obtained when tyrosin, in solution, was oxidized by insect tissue-extract. (Tyrosin is a protein derivative). The wing-cover pigment, as well as both the other pigments just mentioned, could be reduced by confining it in the absence of oxygen with fresh tissue-extract which was rich in reductase activity. The coloration of newly emerged insects could be entirely stopped at any stage by dropping the insects into boiling water and keeping them at that temperature for about 20 minutes. Again, if white, newly moulted insects (*Periplaneta Americana* was used) were submerged in CS_2 and kept there, almost no dark coloration developed. Also (as has been generally found by experience) in order to preserve white grubs and pupae in alcohol without darkening or discoloring, they first had to be treated with boiling water. That is to say, some means (such as heat) appeared to be necessary to destroy the oxidase activity before placing the white adults, grubs or pupae in alcohol; otherwise, the inhibiting action of the strong reductase, present in the living body, rapidly passed after death, and the oxidase (which is injured but not entirely destroyed by alcohol) then brought about oxidation and blackening of the tissues. Likewise, since an oxidase which could oxidize tyrosin was present in the wing-covers and outer integument of *P. cornutus* and the cockroach (*Periplaneta Americana*) it appeared that the cuticular excretion poured out from the hypodermal cells beneath the old integument before it became moulted—the excretion which *went to form* the integument of the newly moulted insect—contained not only the tyrosin-oxidase but also a tyrosin-like derivative (i. e. some similar organic derivative) which oxidized, under the influence of the oxidase, to form the brown or melanic coloration of the integument. These added instances of the activity of an oxidase did not, so far, prove its presence in living cells. The evidence showed, however, that in blood exposed to the air, in extract of the tissues exposed to air, in the cuticular integument of the newly moulted adult beetle and in the tissues of the dead grub and pupæ (killed by some means that does not destroy an oxidase) a very similar, if not an absolutely identical, melanic pigment developed under the influence of an oxidase in every case—and more rapidly as the reductase activity passed. Moreover, these instances of melanic pigment formation served to call to mind the fact that in certain cells of the compound eyes of insects, and of the ocelli of insects and spiders, and in the hypodermal cells forming the circular boundary of ocelli, there was to be quite commonly found a melanic pigment which had its origin *in the cells* during ontogenic development. In view of the proven cases of melanic pigment formation through oxidase action cited above, the inference that the development of melanic pigment in certain eye and hypodermal cells was an example of a similar oxidase acting upon some constituent of the cells, themselves, seemed to have justification. Other similar evidence might be given all tending to show that melanic pigment, in animal tissues, develops through the oxidation of some organic constituent of the tissues—under the influence of an oxidase* acting after the tissue-reductase has been either weakened or destroyed by some means.

In order, then, to learn something finally concerning the effect of a few contact insecticides (when used only in such amounts as were necessary to kill) upon oxidases, catalases and reductases in the living tissues of *P. cornutus,* the method of study was varied as follows:

Insects were killed by the insecticide agent to be studied, using various amounts of the agent for the length of time necessary to kill. The bodies were then extracted by the method already described, as soon as the insects were considered dead or beyond recovery, and the strength of the oxidase, catalase and reductase activities in this extract was compared with that in a fresh extract similarly prepared from the same number of untreated insects. Tests were made in this manner using heat, hydrocyanic acid gas, chloroform and carbon disulphide. It will be appreciated that it was impossible to check the factors of time, original strengths of catalase, oxidase and reductase in the extracts, etc. by this method as accurately as they could be checked in the former method where samples were taken at the same time, from a single extract, for study. Nevertheless, the results showed certain things very satisfactorily.

The extract from gasoline-vapor-killed beetles was always much weaker in reductase activity than the check, while the catalase and oxidase activity remained much the same. For example, when two beetles were treated with about 3% gasoline vapor for 20 hours, it required 4 hours for the treated extract to reduce a certain amount of methylene blue —the check accomplishing the same reduction in 10 minutes. Practically no difference could be seen in the rapidity with which alcoholic guaiac was oxidized; and a check-extract-sample liberated only 2 c. c. more of oxygen from the standard hydrogen peroxide than a similar sample-extract of the insects killed by gasoline.

The extract from beetles killed with carbon disulphide was always quite white or very light straw color at first and it remained so for two or three hours, usually, before it began to darken. That is, oxidase action always appeared to be almost entirely absent, at first. After a few hours, however, this activity became partly recovered. Catalase-action was usually injured one-half or more, and the reductase much less, so that it was relatively strong, at first, as compared with the oxidase activity.

Reductase in the extract of beetles treated 2½ hours with strong chloroform-air was found to be, at the end of that time, 16½ times weaker than the check. The oxidase was apparently uninjured; sometimes it seemed a little more active than in the check. The catalase showed but little injury.

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*Hammarsten (Mandel) in his "Physiological Chemistry" quotes Fürth with Schneider and Prisbram, Gessard, Neuberg and Dewitz as having shown the presence of tyrosinases in insect-tissue and sepia, in melanotic tumors and in pigmented skin.

Hydrocyanic acid gas caused great interference with the activity of the oxidase. For example, three beetles were treated in a cyanide bottle 15 hours and then aired one-half hour before being extracted. This extract remained light or whitish in appearance for 2 hours before it began to darken at the surface in contact with the air, and before it would begin to show any indication of bluing guaiac. The check required only about 2 minutes to bring about a decided bluing of guaiac. The catalase-activity was quite strongly interfered with, at first; but the reductase required only about 9 times longer to reduce its methylene blue than the check.

Extract from beetles kept at 44° to 46° C. for 2½ hours, until dead, showed little loss in catalase activity—but more in its oxidasic and reductase activity. The oxidase was about 7 times slower, and the reductase about 21 times slower than the check.

Clearly, the results given by the last method corresponded very well with results obtained by the former method where the effect of the insecticide upon oxidase, catalase and reductase in the ready-prepared extract was studied. It is true that in every case the beetles were killed by the insecticide agent without the entire destruction of any one of the three enzymes—but never without greatly injuring one or more of them. Also, as will be observed, if the reductase were strongly injured, the oxidasic enzymes were usually little injured or apparently not at all; and conversely, if the oxidase and catalase were greatly injured by the insecticide, the reductase was little injured. Thus, the natural or normal balance of catalase, oxidase and reductase activity was disturbed.

The question may now be repeated: Is this deleterious effect of the insecticides studied, upon the oxidases, catalases or reductases, the cause of death? It is hardly possible that the three enzyme-like bodies named in the question could be so universally present (with activities so apparently coordinated) in tissue extracts and in the living tissues, if they were not of vital importance. They surely accomplish oxidations and reductions in the living tissues and much evidence indicates that they are a part, at least, of the machinery of internal respiration. It has been shown that *P. cornutus* cannot be killed or rendered beyond recovery, by certain contact insecticides studied, without decided injury to one or more of the three activities—oxidase, catalase or reductase. This fact, taken in connection with what has been shown to be true of the influence of those same insecticides upon the respiratory rate and the respiratory-quotient, supports the view that oxidase, catalases and reductases have to do with the starting and carrying forward of cell respiration. If that view is true, then the deleterious effect of the insecticides (named in this connection) upon oxidases, catalases or reductases in insects must be an important factor—perhaps, in some cases, the *determining* factor—in causing death.

No special study has been made of the influence of various contact insecticides upon the protoplasmic activities which carry forward life-processes in the nervous tissue cells of insects. Such a study in this connection would appear to be of next importance, since all the volatile insect fumigants are more or less narcotic in their action. Shiro Tashiro has found, by means of his new apparatus for estimating exceedingly minute quantities of carbon dioxide produced in nerve fibres, that ether and urathane "diminish CO_2 production from isolated nerve fibre"*—although he was not working with insects.

CONCERNING THE INFLUENCE OF GASOLINE-VAPOR, ETC., AND LIME-SULPHUR SOLUTION UPON THE PASSAGE OF OXYGEN, RESPECTIVELY, THROUGH FAT OR LIPOID, AND CERTAIN WAX MEMBRANES.

It has been made clear that gasoline deleteriously affected the reductase activity far more quickly and severely than it did that of the oxidases; and further that, since the presence of a strong reductase tended to partly hold in check oxidase-activity, the quick lowering of reductase-activity in a gasoline-treated extract caused the latter to show greater oxidase power for a while than an untreated check of the same extract. This was true when the test was made with fresh extract in the presence of gasoline vapor. But in such tests as the last, made with extract that had already lost the greater part of its reductase-activity, the fact will be remembered that a less amount of oxygen was used by the "extract plus hydroquinone solution" (and less quinone was formed) in the presence of air containing gasoline vapor than by the check in pure air.

When an extract a few hours old was treated very strongly with gasoline and then test was afterward carried on in fresh air, however, oxidase activity did not appear to have been greatly lessened. The suspicion therefore presented itself that the lessened oxidation of hydroquinone occasioned by the extract in the presence of gasoline-vapor, as well as also the lessened use of oxygen by insects deeply under the influence of gasoline-vapor, was partly due to some other cause than injury of the oxidase or reductase by gasoline.

As has been mentioned several times, the first and most noticeable fact in connection with the tissues of an insect strongly treated with gasoline vapor, as well as with tissue-extract so treated, was the solvent action of the gasoline upon the fats and fat-like bodies (lipoids); or, looked at from the other point of view—the insistent fact was the solubility of the tissue-fats and lipoids for gasoline vapor. Lipoids were found to be present in or around the cells of insect tissues. For example, a semi-transparent lipoid residue was obtained by extracting the *washed* muscles of *P. cornutus* with ether containing a little alcohol. This was perhaps to be expected, since the almost universal occurrence of lipoids, especially such as lecithin, in animal cells and animal fluids has been recognized for several years. This lipoid residue obtained from the washed muscles of *P. cornutus* absorbed gasoline readily. The condition therefore seemed to obtain that wherever the lipoids might be found, in the body fluids (blood)—where they certainly were present—in the protoplasm boundary layer of the cells (Overton) or in the complex of the cell-protoplasm itself, gasoline would surely also be present in an insect under the influence of that insecticide. In any such case the insect tissue cells would be enveloped by blood holding gasoline in solution; the ends of the trachaeoles would be permeated by gasoline. Could

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*Am. Jour. of Physiol., Vol. 32, 1913, No. 11, p. 117.
See also same Journal pp. 137-145.
See also same Journal Vol. 34, 1914, pp. 405-413.

it be that this ready solubility for gasoline of the fats and lipoids of insect-tissues furnished a means for hindering the *absorption* of oxygen by the tissues, or lessening the oxidation of hydroquinone by the oxidase of insect-tissue extract in the presence of gasoline? It seemed that such might be the case, if in fact it should be found that gasoline, held in solution by fats and lipoids, lessened their solubility for oxygen—and by so doing, lowered the rate at which atmospheric oxygen might pass into an extract, or from the trachaeoles (or by any path) through the fluids bathing the cells, on into the cells to those agencies which (in life) utilize the incoming oxygen. Accordingly plans were made to determine what change the absorption of gasoline-vapor by a lipoid membrane, such as a lecithin membrane (or by a fat membrane) would have upon the rate at which oxygen passed through it. For the series of experiments to be made in this connection, it did not seem necessary or even desirable to use the fat or lipoids derived from insects. Clearly, the advantage would lie in eliminating all possible variable quantities. On that account, a comparatively pure fat and lipoid, each of which would be uniform and easily obtained, was desired. Several preliminary quantitative absorptions of gasoline-vapor, using definite amounts (3 grams) of lard, lanolin, lecithin, cholesterin, and (for comparison) egg-yolk and egg-albumen were first carried out. Some representative results of a few of these absorption tests are given in Table VI. The apparatus used was that represented by Fig. III, except that the hooked U-tube "u" and the burette "b" were not needed. The 3-gram quantity of lecithin (or eggwhite, etc.) was placed in a standard stender dish—so that the same absorbing-surface was exposed always—and the dish was then floated upon mercury in the gas-container "g. c." Most of the tests were made over rather short periods, during which the barometer and thermometer remained practically constant. Checks showed that in pure air the volume of gas enclosed with the absorbent (fat, etc.) which was being tested remained unchanged over similar periods of time. In the tests, a loss in volume as shown by the gas-burette was therefore the measure of the "gasoline-vapor" that had been absorbed. At the end of each test the percentage of gasoline-vapor still present was determined from a sample taken from the gas-container—using the "Nordhausen sulphuric acid" method of estimation already described in the former bulletin.

TABLE VI.—COMPARATIVE SOLUBILITY OF GASOLINE-VAPOR IN 3 GRAMS, RESPECTIVELY, OF LECITHIN, EGG-WHITE, ETC.

Exp. No.	Material.	Temperature.	Per cent gasoline vapor at end of test.	Volume measure of gasoline-vapor absorbed.	Time used.
1.	a. Lecithin	22.2° C	3.0%	2.7 c. c	30 min.
	b. Egg-albumen	22.2° C	3.0%	0.6 c. c	
2.	a. Egg-albumen	24.1° C	3.0%	0.7 c. c	40 min.
	b. Egg-yolk (fresh)	23.7° C	3.0%	0.1 c. c	
3.	Egg-yolk (fresh)	25.0° C	3.5%	0.1 c. c	60 min.
4.	Cholesterin	26.8° C	3.0%	0.6 c. c	20 min.
5.	Egg-yolk (fertile egg) after 4 days incubation	24.0° C	4.4%	1.0 c. c	60 min.
6.	Egg-yolk (fertile egg) after 5 days incubation	22.4° C	4.0%	1.8 c. c	30 min.

The lecithin (H. P. from egg, Merck) was used, as received from Merck, in the form of a paste; and in the case of cholesterin the soft dry powder was used. The ready capacity of lecithin to absorb gasoline-vapor, from air containing it, is illustrated in the table. In connection with the solubility of egg-white for gasoline, it must be remembered that even egg-white is not pure albumen, but that it contains a mesh of extremely fine membranes of keratin and a very small amount of fats, lecithin, and cholesterin. The largest absorption of (3%) gasoline-vapor by 3 grms. of egg-albumen was that given in Exp. No. 2 (0.7 c. c.). A surprise came in finding the comparative solubility of fresh egg-yolk for gasoline-vapor as shown in the table. The results obtained in connection with fresh and incubated egg-yolk will be referred to again under the next heading.

After these preliminary tests and other trials, lard was selected as the fat and lecithin as the lipoid which seemed best adapted for the purpose (according to the plan mentioned above) of being spread into membranes to be used in determining the effect of gasoline-vapor upon their permeability to oxygen of the air. However, a few tests were made with membranes composed of a mixture of lard and lecithin, and also with lanoline membranes. All these membranes were prepared, and manipulated to obtain the results required by the plan, as follows:

A very light India muslin was used for the sustaining fabric, and over this the lecithin (or lard, etc.) was spread in a thin sheet entirely covering the fabric and filling its meshes to form essentially a lecithin (or lard, etc.) membrane. In making use of such a lecithin membrane, for example, it was placed as a cover over the mouth of a small preparation dish (4 cm. in diameter), which had been almost but not quite filled with concentrated lime-sulphur solution. The cover was then fastened down "lecithin tight" with a thin metal band, thus enclosing a small air space above the lime-sulphur in the preparation dish. Great care was used in order that the lime-sulphur might not wet the lecithin cover, and the dish was floated up on mercury in the gas container of the apparatus, Fig. III. In this position, the covered preparation dish was allowed to stand a few hours. Then the mercury manometer "m" was adjusted level. The thermometer and barometer readings, the time and the reading of the gas-burette "a" were all recorded. After a certain definite period all these readings were recorded again, the mercury-manometer having been first leveled once more through adjusting the height of the mercury column in the gas-burette "a". In this manner, the rate of volume-decrease of the air in the gas-container "c" was determined. The decrease was due to a decrease in the amount of oxygen in the air of the container holding the membrane-covered dish of lime-sulphur solution. This was definitely proven by determining the percentage of oxygen in the air from samples taken from the container immediately before the tests began and immediately after the last set of readings were recorded—the volume of air used in the container during the test being known. Since the conditions of the experiment have been outlined, it will be clear that this rate of decrease in oxygen was the rate at which oxygen was passing through the lecithin membrane--or whatever membrane was used to cover the preparation dish. From the beginning of the test, the lime-sulphur solution absorbed oxygen gradually and steadily from the small air-space above it. Just as constantly, oxygen was given off from the under side of the membrane (to the small air-space above the lime-sulphur) and *taken up* or *absorbed* by the upper surface of the membrane from the air of the container—the volume of which was comparatively large. The prime condition was (it will be remembered) that the lecithin cover (or lard, etc.) closed the preparation dish "lecithin tight." No oxygen could pass into the air space of the dish except it passed through the lecithin itself. When the rate at which oxygen passed through the membrane from air had thus been determined, the mercury mug "b" was raised, cocks "a" and "c" were opened and as much of the air as possible was carefully expelled.* Then, from a stock preparation, gasoline-air was drawn into the container as the mercury mug "b" was lowered. At first, gasoline-vapor was absorbed rapidly by the lecithin membrane. By making tests (as already described) at intervals, it was found that the rate of decrease in volume would finally settle down to a fairly uniform rate. That is, the membrane would finally become saturated with the gasoline-vapor, and the decrease in volume after that was due to the loss in oxygen absorbed by the lime-sulphur solution. This last rate was then determined as accurately as possible (just as has been explained when the cup was in air.) Here also, the direct method of measuring the loss in volume of oxygen could be checked by taking samples of gasoline-air at the beginning and at the end—making determinations of the percentage of gasoline and of oxygen present at each time and thus figuring the rate at which oxygen had been absorbed. Now this last rate in the loss of oxygen, it will be observed, was the rate at which oxygen passed through the same lecithin membrane after the latter had become saturated with gasoline-vapor in the presence of gasoline-vapor-air. The rate at which oxygen passed through the lecithin membrane in air might therefore be compared with the corresponding rate when the membrane was under the influence of gasoline-vapor. In many of the experiments, the covered preparation dish was taken from the container and aired until as much as possible of the gasoline-vapor had evaporated from the lecithin cover. After that the dish was carefully replaced in fresh air in the container and the rate at which oxygen passed through the membrane again determined. This was done, as a check, to learn whether the lime-sulphur solution was still in condition to absorb oxygen at a practically uniform rate when the membrane was exposed to pure air.. Further precautionary checks were made by finding the rate at which the uncovered dish of lime-sulphur absorbed oxygen in pure air and in gasoline air. These checks showed conclusively that at the end of the series of tests the lime-sulphur solution was still active enough to absorb oxygen much more rapidly than the lecithin or other membranes could take up that gas and pass it through to the absorbing solution, either in pure air or gasoline-vapor-air. In all cases, the temperature during any series of tests was kept as uniform as possible. When the thermometer or barometer changed appreciably, or whenever the tests extended over more than three hours, all gas-volume measurements were changed to 0° C, and 760 m. m. mercury pressure before comparisons were made.

Over 35 trial experiments were made with the apparatus in learning the best thickness of membrane to use, and the time-limits (in order that the lime-sulphur solution should not be weakened too much), as well as many other details. Thereafter, twelve series of tests were run to determine the influence of gasoline-vapor upon the rate of oxygen transfer through lecithin, lecithin-lard and lanolin membranes. The lecithin-lard mixture was made of about equal parts of lecithin and lard thoroughly mixed together. In half of these both methods mentioned were run together—i. e. the method of total gas-volume measurements, and the method of percentage determinations of the oxygen, gasoline-vapor, etc., present at the start and the end of each separate test in the series. The cautionary checks were also observed. Four series of tests were run to determine the influence of chloroform-vapor upon the rate of oxygen transfer through lecithin membranes. These four series of tests were carried out by the one method only—namely, that of the total gas-volume measurements at the beginning and end of each test.

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*The edge of the metal band, which was used around the top of the preparation dish to fasten the cover-membrane tightly, projected above the surface of the latter enough to entirely protect it from damage by the top of the container when the air was being expelled.

The results of all the experiments by both methods pointed directly to the conclusion that, in the presence of gasoline-vapor air or chloroform-vapor air, the membranes named permitted less oxygen to pass per unit of time than they permitted in air only.

Note that the experiments with the covered preparation dish of lime-sulphur were carried out under the conditions encountered regularly by the tissue cells of an insect subjected to fumigation by gasoline-vapor or chloroform-vapor. Just as oxygen reached the lime-sulphur for absorption at a lower rate, when passing through the lecithin membrane in the presence of gasoline-vapor or chloroform-vapor, so, it may be judged, less oxygen would be able to reach the oxygen-absorbing protoplasm of the cells through the surrounding body fluids (blood) etc., the lipoids of which held gasoline-vapor. So also, in the presence of air containing that vapor, less oxygen would be able to pass through the surface of an insect-tissue extract (containing hydroquinone, for example) into the extract where it could be utilized by the oxidase in oxidizing hydroquinone.

Now, the actual percentage of oxygen present in the gasoline-vapor air would naturally be lower than in normal, pure air through dilution by the gasoline-vapor, but it appeared that this alone could not fully account for the lower rate of oxygen transfer through the membranes. Attention may be called to the fact that when the percentage of oxygen in the air of the container, for the "air only" tests, was made as nearly equal as possible to the percentage of oxygen in the gasoline air used (see Nos. 3 and 4, Table VII), the rate of oxygen transfer through the membrane remained lower, nevertheless, in the presence of gasoline-vapor. In Exp. 3 (Table VII) the oxygen percentage was 20.2 at the beginning, and 18.26 at the end of test No. 1. In test No. 2, carried out in "gasoline-vapor air" mixture, 18.26 per cent oxygen was present at the start and 17.5 per cent, at the end. Test No. 3 of Exp. 3 was started after the covered preparation dish had been aired several hours. All the gasoline had not been given up by the membrane, however—and by the end of the test, the small percentage of gasoline-vapor shown in the table had been given off to the air of the container. A very thick lecithin-lard membrane had been used. In Exp. 4 (test No. 1) of the same table, the percentage of oxygen at the beginning was 15.13, and at the end, 13.2. In test No. 2 of this experiment, the gasoline-vapor air contained 14.6 per cent oxygen at the start, and 13.11 per cent at the end. The conclusion in regard to this point must be, therefore, that the gasoline-vapor which was taken up by the membranes rendered them less permeable to oxygen. Representative results are given in Table VII.

TABLE VII.—SHOWING THE INFLUENCE OF GASOLINE-VAPOR, CHLOROFORM-VAPOR AND LIME-SULPHUR SOLUTION UPON THE PASSAGE OF O_2 THROUGH CERTAIN SPECIFIED MEMBRANES.

Exp. No.	Test No.	Membrane cover used.	Insecticide-vapor used.	Per cent of Insecticide-vapor at end of test.	Temp. Cent.	Total time exp. ran.	Total O_2 absorbed.	O_2 absorbed, or O_2 passing through membrane per period of 10 hrs.	Excess of O_2 passing through membrane per 10 hr. period in pure air over that in insecticide-vapor-air mixture.
1.	1.	Lecithin	Air only		23.2° C. to 22.6° C.	2¾ hrs.	3.8 c. c.	13.8 c. c. } Average	
	2.	Lecithin	Air only		23.3° C.	1 hr.	1.5 c. c.	15.0 c. c. } 14.4 c. c.	10.4 c. c.
	3.	Lecithin	Gasoline vapor	2.8%	24.2° to 21.4°	15 hrs.	6.1 c. c.	4.0 c. c.	
	4.	Lecithin	Gasoline vapor	3.5%	21.4° to 20.4°	3⅙ hrs.	2.42 c. c.	7.6 c. c.	6.8 c. c.
	5.	No cover	Gasoline vapor	4.4%	26.9° to 25.6°	3¼ hrs.	3.8 c. c.	10.8 c. c.	
	6.	No cover	Gasoline vapor	4.4%	25.6°	¾ hrs.	0.8 c. c.	10.6 c. c.	
2.	1.	Lecithin	Air only		25.6° to 27.4°	1⅔ hrs.	1.6 c. c.	9.6 c. c.	
	2.	Lecithin	Gasoline vapor	2.7%	24.8° to 25.4°	3 hrs.	1.47 c. c.	4.9 c. c.	4.7 c. c.
	3.	No cover	Gasoline vapor	3.7%	28.2° to 27.4°	2 hrs.	1.6 c. c.	8.0 c. c.	
3.	1.	A thick Lecithin—lard cover	Air only		25.2° to 24.4°	24 hrs.	2.4 c. c.	1.0 c. c.	0.809 c. c.
	2.	A thick Lecithin—lard cover	Gasoline vapor	5.37%	25.0° to 27.2°	24 hrs.	0.46 c. c.	0.191 c. c.	
	3.	A thick Lecithin—lard cover	Air (gasoline vapor)	0.55%	27.2° to 24.0°	24 hrs.	1.17 c. c.	0.48 c. c.	0.52 c. c.
	4.	No cover	Gasoline vapor	5.7%	22.4° to 21.4°	4 hrs.	2.07 c. c.	5.17 c. c.	
4.	1.	Lecithin—lard	Air only		25.0°	6 hrs.	3.5 c. c.	5.83 c. c.	3.45 c. c.
	2.	Lecithin—lard	Gasoline vapor	4.54%	26.6°	6 hrs.	1.43 c. c.	2.38 c. c.	
	3.	Lecithin—lard	Air again		27.2° to 26.6°	6 hrs.	2.05 c. c.	3.4 c. c.	
	4.	No cover	Gasoline vapor	5.1%	22.8° to 22.0°	4 hrs.	1.98 c. c.	4.95 c. c.	
5.	1.	No cover	Air only		24.2°	4-5 hr.	1.8 c. c.	22.5 c. c.	
	2.	No cover	Chloroform vapor		25.4°	1½ hr.	1.5 c. c.	10.0 c. c.	
	3.	Lecithin	Chloroform vapor		25.0°	1 hr.	0.5 c. c.	5.0 c. c.	11.0 c. c.
	4.	Lecithin	Air only		25.2°	1 hr.	1.6 c. c.	16.0 c. c.	
	5.	No cover	Air only		25.0°	2 hrs.	3.7 c. c.	18.5 c. c.	
6.	1.	No cover	Air only		20.0°	1 11-12 hrs.	2.3 c. c.	12.0 c. c.	
	2.	Lecithin	Air only		20.0°	2 hrs.	2.0 c. c.	10.0 c. c.	4.0 c. c.
	3.	Lecithin	Chloroform vapor		21.0° to 21.4°	1 hr.	0.6 c. c.	6.0 c. c.	
	4.	No cover	Chloroform vapor		19.8° to 20.0°	1⅓ hrs.	1.5 c. c.	11.2 c. c.	
7.	1.	Bees wax membrane	Air only		27.0°	⅔ hr.	1.2 c. c.	18.0 c. c.	
	2.	Bees wax membrance wet with lime-sulphur solution	Air only		25.2°	48 hrs.	18.46 c. c.	3.8 c. c.	14.2 c. c.
	3.	No cover	Air		25.2°	1 hr.	1.2 c. c.	12.0 c. c.	
8.	1.	Shellac	Air		26.0°	1 hr.	1.4 c. c.	14.0 c. c.	
	2.	Shellac wet with lime-sulphur	Air		25.6° to 25.4°	2⅔ hrs.	1.6 c. c.	6.0 c. c.	14.0—6=8.0 c. c.
	3.	Shellac wet with lime-sulphur	Air		25°	7-12 hrs.	0.1 c. c.	1.7 c. c.	14.0—1.7=12.3 c. c.
	4.	Shellac wet with lime-sulphur	Air		25.0° to 24.8°	50 hrs.	1.1 c. c.	0.22 c. c.	14—0.22=13.78 c. c.
	5.	No cover at end	Air		24.8° to 25.0°	1 hr.	1.7 c. c.	17.0 c. c.	

Before figuring the rates given in Table VII, all gas-volumes were reduced to 0° C, and 760 m. m. mercury pressure. Since all tests were not run for equal periods of time, it was necessary to figure results to some certain period—a ten-hour period was used. Results of experiments with gasoline-vapor are those obtained through estimating the actual amount of oxygen present at the beginning and end of each test. Where two or three determinations were made, the value given under any test number in the table is the value which came nearest the average. As has already been mentioned, however, all determinations (by both methods) led to the same general conclusion already stated.

In this connection, it occurred to the author that a good opportunity had presented itself for testing the effect of lime-sulphur, itself, upon the permeability of a wax membrane to oxygen. Accordingly two series of tests, results of which are given under Nos. 7 and 8 of Table VII, were carried out, using bees wax and shellac membranes. The membranes were formed by dipping thin India linen in melted beeswax, and in melted shellac, until membranes of the desired thickness were obtained. After the tests with a dry membrane had been carried out, the preparation dish (over which the membrane was fastened as a cover) was inverted and shaken until the lime-sulphur in the dish had thoroughly wet the surface of the membrane inside the dish. Before test No. 2 of Exp. 8 was tried, the preparation dish was only shaken. It was again thoroughly shaken, before test No. 3; and before the fourth test the dish was inverted—the lime-sulphur solution being left in contact with the shellac membrane, thus, for 25 minutes. In that time, the solution had "taken hold" and thoroughly wet the membrane. Note the decline in the rate of oxygen transfer. Both sets of tests showed that much less oxygen was absorbed (i. e. passed through the membrane) after the membrane-surface, inside the preparation dish, had been wet with the solution. That is, the lime-sulphur solution rendered the wax membranes decidedly less permeable to oxygen—less able to transmit oxygen. There seems to be no reason why lime-sulphur* would not have the same effect upon the wax covering of a scale insect, such as that of the *San Jose* scale.

A few experiments had been made a long while ago with living grasshoppers (*Melanoplus*) in air containing very strong fumes of osmic acid. These insects were darkened, and were rendered clumsy in their movements, but they lived for many hours in the fumes of the acid. It seemed a wonder that they could thus withstand the fumes—and that the fumes did not penetrate. In addition to the membrane-experiments just recited, therefore, one set of tests was carried out to determine the rate at which oxygen from air could pass through a lecithin-lard membrane before and after the membrane had been exposed to strong osmic acid fumes. Oxygen passed through the membrane at the rate of 1.3 c. c. per hour before treatment with the fumes. The membrane was treated (from one side) with the fumes for over three hours. It was then aired over night, and on the next day, in the three tests made, the darkened membrane did not transmit oxygen at a greater rate than 0.2 c. c. per hour—i. e. the rate was about six times slower than before the treatment. The lecithin-lard membrane was penetrated by the fumes but slowly.

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*Some other scalecide properties of lime-sulphur are given in Tech. Bull. 11.

(The very poor penetrating power of osmic acid fumes, when used as a histological killing agent, are well known.) It may only be suggested here that perhaps the first effect of osmic acid fumes in blackening lipoids and fats in the experiment-membrane (or the surface of a living grasshopper, etc.) is to establish a black surface-membrane at once which is not only a little less permeable to oxygen, but also much less permeable to the osmic acid fumes, themselves.

THE EFFECT OF TEMPERATURE ON THE CAPACITY OF LIVING INSECT TISSUES FOR THE ABSORPTION OF CERTAIN GASES OR VAPORS.

In Table VI results are given of gasoline-vapor absorptions by 3-gram samples of egg-albumen, and also by the same amounts, respectively, of fresh unincubated egg-yolk and of fertile egg-yolk after four and five days of incubation. It was a surprise, in these tests, to find that gasoline vapor was about six times more soluble in egg-albumen than in the fresh egg-yolk, although the latter contained fats and fat-like material in the greater amounts by far. All other tests, so far carried out, had shown fats and lecithin to have greater capacity for the absorption of gasoline-vapor than egg-albumen. The exception, therefore, seemed so interesting and so possibly significant that it was decided to test the absorption capacity of the yolk for gasoline-vapor after certain periods of incubation. The yolk of infertile eggs, even after several days of incubation, was found to give the same results as yolk taken from fresh unincubated eggs. In the case of incubated fertile eggs the young, developing embryo was stirred up with the yolk before the 3-gram sample for the absorption test was taken. A comparison of such results of yolk-absorptions as are given in Nos. 2 and 3 with those given in Nos. 5 and 6 of Table VI seemed to show that the solubility, for gasoline-vapor, of fats and lipoids in the yolk changed greatly in the four and five days of incubation. The first few hours of incubation did not bring about a measurable change in the capacity of the yolk to dissolve gasoline-vapor. All the tests with yolk samples as given in the table were made at a room temperature of 25° to 26° C. Four tests with yolk samples of only a few hours incubation were made in a small incubation room at 103° F. These gave practically the same results, as to absorption capacity, as similar tests at the ordinary room temperature; if there was any increase in that capacity, it was not great enough to measure. As is well known, on about the fourth and fifth days of incubation the embryo of the hen's egg begins to show quite decided respiratory activity, and a period of rapid development begins. It was at this period of incubation that the decided increase in the capacity for absorbing gasoline vapor was shown by the embryo-yolk-mixture.* Here was an interesting change, (an increase) in the absorption capacity of the yolk-mixture for gasoline vapor, which seemed to be related with the changes that made for active development in the embryo. As long as the embryo remained comparatively dormant (or, was unable to develop through non-fertilization, when incubated) the capacity for absorbing gasoline vapor remained comparatively low. These facts surely seemed significant in connection with the behavior of gasoline vapor, and the like, toward dormant insects.

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*Attention should be called to the fact that absorption results in 5 and 6 are much greater than the absorptions given by egg-albumen (i. e. egg-white). It would seem that the change in the embryo-yolk-mixture, which occasioned an increase in the gasoline-vapor absorptions, was probably a change in the fats and lipoids. The amount of alcohol-soluble material in the embryo is said to increase rapidly with development.

It is a well known rule that dormant insects are harder to kill with fumigants (such as gasoline vapor, carbon disulphide, etc.), and that they are more resistant to sprays of kerosene emulsion and the miscible oils in general than are active insects of the same species. The question naturally arose in this connection, therefore, as to whether insects in the dormant state, from cold say, might not absorb less gasoline vapor under a given fumigation charge than they would absorb when in the active condition. In view of the close relation which the question bore to the main problem of how contact insecticides kill, experiments were planned to determine whether dormant insects would take up less of such a fumigant as gasoline vapor than would be taken up by the same insects after they had been brought into an active condition.

Hibernating Luna moth pupae were selected as the first insects to be used in these experiments, and gasoline vapor was the fumigant chosen. This fumigant was used again in this case for the reason, already mentioned several times, that it permitted of accurate percentage determinations of itself and of the oxygen and carbon dioxide present in the air in which it was used. The pupae had been kept in the cold room of the insectary all fall and winter until the experiments were first undertaken December 17, 1913. The apparatus represented in Figure III (except for the hooked U-tube, and the burette "f") was moved into the cold room six to eight hours before an experiment was to be begun, in order that everything might reach the temperature of that room. Among the accessories was a separate gas container with a stock supply of gasoline-vapor-air, and a little water to maintain saturation with water vapor. The dormant pupae were floated up on mercury in the gas container "c", Fig. III. The mercury in the container was raised until almost all air was expelled and the pupae were near the top. The outlet cock "t" of the container "c" was then connected with the stock-container of gasoline-vapor-air and the required amount of gasoline-vapor-air was quickly drawn in with the pupae. Within the next half minute, a sample of the gasoline-vapor-air with the pupae was drawn off above mercury into a separate gas-container, to be kept for percentage estimations. The mercury manometer, "m" Fig. III, was quickly leveled and the apparatus was then watched until the first rapid loss in volume had passed, and the manometer showed that no more gasoline vapor was being absorbed. Then, a second sample of the gasoline-vapor-air confined with the insects was drawn off for estimation in the same manner as the first. Both the samples (one taken at the beginning and one at the end of the test) were removed to the laboratory and allowed to stand until they reached the temperature of the room and of the apparatus (i. e. gas-pipettes and compensation burette;[*] (see Fig. 4, p. 27, Tech. Bull. 11, this station) used in making the percentage estimations. After that, the percentages of gasoline vapor, of carbon dioxide, and of oxygen present at the beginning and at the end of the absorption test with the pupae were determined. From these results, knowing the volume of gas present with the insects at the beginning, the amount of gasoline vapor present at the start, and the amount absorbed, could be figured.

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[*] By means of this burette, direct volume measurements at 0°C. and 760 m. m. mercury pressure, with proper water vapor-tension corrections, could be made.

At the end of the absorption test, the pupæ were carefully removed from the container and aired. They were then brought into the laboratory, where they might warm up and start active development. After their actions, taken in connection with respiration tests, showed that they were in an "active state", an absorption test with gasoline-vapor-air (using as nearly as possible the same percentage and the same amount of gasoline vapor) was carried out in the warm room by the same method as in the former case.

Two separate experiments with Luna moth pupae, entailing the complete sets of estimations just outlined, were carried out by this method. Results of these two experiments are given in Table VIII, Nos. 1 and 2.

TABLE VIII.—INSECTICIDE-VAPOR ABSORPTIONS OF COLD (DORMANT) AND WARM (ACTIVE) INSECTS.

Exp. No.	Insects.	Vapor used.	Temperature.	Volume of vapor absorbed.	Time.
1.	6 Pupae of Luna moth; 15 grms...	Gasoline vapor 2.6%......	9.2° C.......	0.38 c. c.....	2 hrs.
	6 Pupae of Luna moth; 15 grms...	2.8%........	24.6° C......	1.13 c. c.....	2 hrs.
2.	9 Pupae of Luna moth; 20 grms...	Gasoline vapor 2.12%.....	7.2° C.......	0.35 c. c.....	1 hr.
	9 Pupae of Luna moth; 20 grms...	2.4%........	24.8° C......	0.89 c. c.....	1 hr.
3.	5 Passalus cornutus, 10 grms......	Ether........	0.6° C.......	1.2 c. c......	10 min.
	5 Passalus cornutus, 10 grms......	Ether........	0.6° C.......	1.4 c. c......	30 min.
	5 Passalus cornutus, 10 grms......	Ether........	22.2° C......	6.0 c. c......	10 min.
	5 Passalus cornutus, 10 grms......	Ether........	22.2° C......	7.5 c. c......	30 min.
4.	5 Passalus cornutus, 11.2 grms....	Ether........	−1.0° C.....	2.40 c. c.....	10 min.
	5 Passalus cornutus, 11.2 grms....	Ether........	−1.0° C.....	2.45 c. c.....	15 min.
	5 Passalus cornutus, 11.2 grms....	Ether........	23.4° C......	5.2 c. c......	10 min.
	5 Passalus cornutus, 11.2 grms....	Ether........	23.4° C......	5.4 c. c......	15 min.
5.	5 Passalus cornutus, 10.5 grms....	Ether........	−2.0° C.....	0.7 c. c......	10 min.
	5 Passalus cornutus, 10.5 grms....	Ether........	−2.0° C.....	0.8 c. c......	20 min.
	5 Passalus cornutus, 10.5 grms....	Ether........	24.0° C......	5.1 c. c......	10 min.
	5 Passalus cornutus, 10.5 grms....	Ether........	24.0° C......	6.0 c. c......	20 min.
6.	5 Passalus cornutus, 10 grms......	Ether........	−2.4° C.....	0.4 c. c......	10 min.
	5 Passalus cornutus, 10 grms......	Ether........	−2.4° C.....	0.5 c. c......	20 min.
	5 Passalus cornutus, 10 grms......	Ether........	About 20.0° C.	1.2 c. c......	10 min.
	5 Passalus cornutus, 10 grms......	Ether........	About 20.0° C.	1.5 c. c......	20 min.

At the beginning of Exp. No. 1, in the cold room, there were 2.08 c. c. of gasoline vapor present in the air with the pupæ. The table shows that 0.38 c. c. of the vapor was absorbed—that is, only 0.18 of all the gasoline vapor present at the start was absorbed by the six pupae. The latter were all alive when brought into the warm room. They were kept in moist air and their activity increased. By the third day, the respiration had increased to more than three times its rate in the cold room. On the sixth day, the rate was about the same or slightly less. The pupae were kept in the warm room 17 days, in all, before the last absorption test was made. Since, by the method used, not all the air was expelled from the container before gasoline-air was drawn in with the pupae above the mercury, it was impossible to make sure that the percentage of gasoline vapor used in the warm room was *just* the same as was used in the cold room test. As may be seen by the table, however, it was possible to make the percentages *almost* or *practically* the same. In the warm room test of Exp. 1, there were 2.24 c. c. of gasoline vapor present in the air used, and 0.5 + of all this was absorbed by the same pupae which in the dormant stage had absorbed only 0.18 + of the 2.08 c. c. of gasoline vapor placed with the air used in the cold room test.

When the nine pupae, used in Exp. 2, were removed from the gasoline-vapor-air at the end of the test in the cold room, they had become quite sensitive to touch. They would wriggle actively when touched. The gasoline vapor seemed to have stimulated them. They were removed to the warm room and kept there about 15 days before the second absorption test was run. In this experiment 1.96 c. c. of gasoline vapor was present in the air at the beginning of the warm room test, and 0.45+ of this vapor was absorbed by the pupae as against only 0.2 + of the 1.7 c. c. of vapor present in the air during the cold room test. About 80 c. c. of gasoline-vapor-air was present at the end of each test. The ratio of the *absorbed* gasoline vapor to the whole amount present was, in both experiments, greatest in the warm room tests where the insects were undergoing active development. All the pupae recovered at the end of the tests, and the first moths began to emerge about five days after the last tests in each experiment. Adults emerged from all the pupae, although none were very perfect moths. After the above experiments, it was decided to use adult *Passalus cornutus* in absorption-tests made, first, when the beetles were quiet and dormant from cold, and again when they had become active in the warm room. These beetles were chosen because, as has been explained in Bulletin 11, all of the air could be safely forced out from around these insects by mercury. Thus, it was possible to introduce samples of the *same* stock of insecticide-vapor-air into the container, unmixed with other air, in the cold room and in the warm room. Air that was almost, but not quite, saturated with the insecticide vapor at the cold room temperature was kept in a gas container above mercury as the stock-supply. One could, in this way, be sure that the percentage of insecticide vapor present, in both tests, was exactly the same. With this assurance that the same percentage of the insecticide vapor could be placed with the insects in the two different tests, it was not necessary to use a vapor which would permit of accurate quantitative estimations of the percentage present at the beginning and end of each test. Thus, different apparatus and a different method might be employed. The method of measuring the total rapid decrease in volume could be depended upon, it appeared, to show the volume of insecticide vapor absorbed by the insects. Experience had shown that most of the vapor-absorption would take place in an interval too short for respiration to make an appreciable change in volume. Moreover, in the short interval necessary, barometer and therometer readings remained practically the same. The apparatus used for making the gas measurements was the compensation-burette just referred to (Shown in Fig. 4, Tech. Bull. 11, and a gas-container of the type shown at A., Fig. 7, Tech. Bull. 11 of this station.

A certain measure of the insecticide vapor to be used was transferred from the stock supply into the compensation burette. The beetles were floated, dorsal side up, on mercury in a gas-container, and the mercury was raised until all air was expelled from around them. The container was at once connected with the compensation gas-burette, and the accurately measured sample of insecticide vapor was quickly drawn over with the beetles. After 10 minutes the whole remaining volume was returned to the compensation-burette and again accurately measured. The first reading minus the second reading of the compensation burette showed the amount of vapor that had been absorbed by the insects. The gas could thus be transferred back and forth at intervals to obtain absorption values at 10, 20 and 30 minute intervals, if desired. At the end of this test in the cold room, the beetles were removed to fresh air; and after an hour or two were brought into the warm room along with the apparatus and the stock supply of insecticide vapor. After 18 to 41 hours, when the beetles had become active and everything to be used had reached the room temperature, absorption-tests were again carried out with the same insects—using a sample of the same insecticide vapor under the new conditions. Now, gasoline did not produce a very high percentage of vapor at the cold room temperature; and a fluid which would give a higher percentage of vapor at the low temperature seemed desirable. On that account, ether was selected for the new trials instead of gasoline.

Four experiments were carried out in the manner just outlined, using *P. cornutus*, and the vapor of ether in air. The results of all four of the experiments are given in Table VIII. In no case, as may be seen, were the absorptions less than two times greater in the warm room, where the beetles were active, than when the latter were dormant in the cold room. In experiments 3, 4 and 5, in the cold room, the small amount of absorbed ether-vapor stimulated the dormant insects until they twitched the antennae and moved the legs. On the other hand, in the warm room tests of Exp. 3, the active beetles had become entirely motionless (anaesthetized) in 10 minutes; at the end of Exp. 4, only a bare movement of the antennae could be noticed, still; and in the warm room test of Exp. 5, the active beetles were completely anaesthetized by the end of 20 minutes. In the case of Exp. 6, the beetles were entirely stiff and helpless at minus 2.4° C., and they remained so even under the influence of the small amount of ether absorbed. When these insects were removed from the first test, they showed no movement whatever; and they recovered from the cold, only slowly, after being brought into the warm room. They had been kept in the cold (at minus 2.4° C.) only a few hours in all. A different stock supply of ether-vapor-air was used in Exp. 6, and the five beetles absorbed only 1.5 c. c. of the vapor even in the warm room in 20 minutes. This was barely enough of the ether to place the insects in the excitement state—they were more active at the end than at the beginning of the last test.

In order to show how nearly constant a certain volume of pure air remained during a period of 30 minutes with five beetles, a single check may be related. The five beetles used weighed 10 grams. The 50 c. c. of pure air was transferred from the compensation burette to the container with the beetles and back again three times during the check, with the following results:

50.0 c. c. at the beginning;
50.2 c. c. at end of 10 min. (after first transfer);
50.0 c. c. at end of 20 min. (after second transfer);
49.9 c. c. at end of 30 min. (after third transfer).

The six experiments (Table VIII) were carried out with such care, and were checked in such a manner, it is believed, as to make the apparent conclusion seem undoubted. In the dormant condition, the insects absorbed less gasoline vapor and less of the vapor of ether than did the same insects when active. The difference in solubility of the insecticide vapors in the dormant and in the active insects, was so great that ordinary charges of the insecticides used did not bring the concentration of the insecticide, within the body tissue of the dormant insects, to the danger point. Thus, the lowered absorption capacity, which accompanied the dormant condition, may easily furnish the chief explanation of the fact that insects, dormant from cold, are harder to kill by ordinary fumigants and by ordinary miscible oil, contact sprays.

Evidence has been given that the tissue fats and lipoids of living insects should be considered as the principal solvents of such insecticides as gasoline and kerosene vapors, ether and the like. The suggestion made in connection with egg-yolk absorptions, therefore, seems proper here. Namely, the changes, which accompanied respectively an active or a dormant state, occasioning an increase or decrease in the capacity for absorption of insecticide vapors, was probably a change in the condition of the tissue fats and lipoids—or, in their relation to the other cell constituents..

IN REGARD TO THE MANNER IN WHICH BORAX AND SOME OTHER POWDERS (SOLID CONTACT INSECTICIDES) BECOME EFFECTIVE AGAINST CERTAIN INSECTS.

Mention has already been made (Technical Bulletin 11) of certain dry powdered solids that may be applied as contact insecticides. In the case of pyrethrum powder, attention was called to the fact that, as applied in most cases, the principal influence of this insecticide is due to the volatile bodies held in the powder. This is very clear when the insect is confined in a warm air-space with some of the powder. However, certain insects (for example diptera and grasshoppers) may sometimes be overcome—for a time, at least—by dusting their bodies with the powder, even in the open air. When such insects are examined, one may often observe with a binocular microscope that some of the powder becomes lodged in the dry vestibule of the tracheæ within the spiracles, and no doubt the volatile bodies from the powder charge the air in the tracheal system. The poison in such cases, therefore, really becomes absorbed as a gas or vapor. Nevertheless, it is possible in the case of some insects for certain dry non-volatile powders to become effective as contact insecticides. White hellebore (although it contains a slightly volatile body) does not kill insects confined in the air with it at ordinary temperatures, provided they do not come in contact with the poison—or do not eat it. It is well known that the fresh hellebore powder is a stomach poison to insects; it may be observed to be effective as a contact insecticide also, with moist rose slugs. I have watched many young rose slugs that did not *attempt* to eat after their bodies had been powdered with fresh hellebore. If they attempted to crawl, the body seemed to be clumsy as if the hypodermal sense organs had been numbed; and usually, the slugs would fall from the leaf. Slugs, in this condition, were kept for varying lengths of time (up to nearly two days) until they died.

It was clear that the body secretions had dissolved some of the hellebore, and had moistened more of it so that it stuck as a white crust on the body. The indications were that but very little of the hellebore, dissolved in the body secretions, had been absorbed through the cuticular covering—only enough to render the outer surface of the body numb and clumsy. In the final stages, the insect seemed to be dying, more from drying and from starvation than anything else—yet it was the hellebore which first rendered the animal in an unfit condition for normal life-processes.

Borax powder and finely powdered sodium fluoride have been used as effective agents against cockroaches. It was known to be not at all necessary to place these powders on a bait that should be eaten by the roaches; the dry powders became effective if they were dusted in locations where the insects were sure to run. There seemed to be nothing appetizing about the powders, in themselves, and it was a question *how* they became effective against roaches. The large American cockroach (*Periplaneta Americana*) and the smaller croton bug were available for study in this connection.

In the first tests, a little dry powder of borax, or of sodium fluoride was sprinkled on one-half the bottom of wide, flat, glass-covered culture dishes. Then single roaches were introduced and watched. It was soon noticed that when a roach ran through either the borax or the sodium fluoride, a little of the dry powder stuck to the lower part of the body and to the legs—especially at the bases of the legs, and between the sternal plates. Also, the insect was almost sure to get its antennae dusted with the powder as it waved them about. If left to itself, a roach that had become powdered in the manner just described would soon settle down and begin "cleaning up." In this latter process, the long antennae were drawn across the mouth and licked clean—the feet and legs and body were licked. After a time, a roach that had been cleaning itself of either of the powders named would begin to show uneasiness and irritability. It was apt to become sick, after a time, and exude a drop of saliva from the mouth. Finally, the insect would become dumpy, often remaining quiet for long intervals, only to start up suddenly and nervously, and then lapse again. Such actions were usually followed by partial paralysis of the hind and middle legs. The wings and feet twitched at intervals, and gradually the body became more helpless until death resulted. This might all take place in anywhere from four to forty-eight hours; and the length of time before death would result seemed to depend in great part upon the amount of powder the roach had cleaned from his body. As a rule, the sodium fluoride acted very much more rapidly than the borax—requiring only four to twelve hours. Sometimes a roach that had taken only a little borax, in cleaning the powder from its body, would pass through the first stages of uneasiness (and apparent stomach-sickness) and then recover so far as to eat, and act normal for four or five days, perhaps—after which it would become dumpy. It would then eat no more. The wings would quiver when the insect was disturbed; paralysis of the legs would finally set in, and gradually the body would become more helpless in every case until death resulted.

Observations were made, and record was kept (from treatment to death) of the actions of 45 of the insects treated with borax, sodium fluoride, or borax and pyrethrum mixed. A few tests were made by compulsory feeding of the roaches with a very little borax or sodium fluoride from the point of a small knife-blade. In every case the symptoms were much like those described above and the insects finally died. These last tests made it clear, therefore, that both borax and sodium fluoride could act as stomach poisons in the case of the cockroach. Moreover, it seemed very likely that in cleaning either of the powdered poisons from antennae, feet and body, the insect would eat enough of the poison to kill. Finally, visible proof was obtained that powder, licked from various parts of the body, was swallowed. Sodium carmine was very thoroughly dried and pulverized with borax, and with sodium fluoride. Insects were placed with this stained powder, and several hours after they had cleaned it from their bodies, dissections were made; the red stain was found in the contents of the crop.

The question still remained, however, as to whether a little of the powdered insecticides might not be dissolved in the moist exudations at the bases of the legs and between the sternal plates, and then absorbed through the thinner body integument in the locations named. It seemed possible also that the very fine powder might enter the spiracles. That is, it was still a question as to whether the powders under consideration might not be contact insecticides as well as stomach poisons when used against roaches. In order to get at the solution of this question, it was found to be absolutely necessary to devise some way of preventing the insects from licking their bodies after they had become dusted with the powder—without, at the same time, inflicting any serious mechanical injury in the use of the preventative device. The desired result was accomplished by means of card board collars, which were prepared and used in the following manner:

The collars were made from single pieces of flat bristle board of about the weight of ordinary medium index cards. Each collar was four to four and one-half inches in diameter—i. e. large enough to form a cover over a shallow glass stender dish. A slit was cut in the circular card from the circumference to the center, where a small smooth hole was punched. This central opening was large enough to turn freely on the neck of a cockroach, but it was very much smaller than the animal's head. After the collar had been very carefully placed around the neck of a roach, a thin strip of paper was afterward pasted over the slit. The flat collar could then be placed over the stender dish, containing a little powder to be tested, so that the insect's body rested upon the bottom of the dish, and the head stuck up above the collar outside the dish. The fluttering wings and scrambling legs would thoroughly dust the animal's body without any of the powder's reaching the head or mouth. Fig. No. 4 of Plate I shows the position of the head of a cockroach wearing such a collar. In check tests, untreated roaches were made to wear collars for eight, eighteen, and even ninety-eight hours without any serious injury. After these specimens were released, they were kept under observation for ten to nineteen days, and during that time fed and behaved normally. In all these experiments the roaches were permitted to have moist food when no insecticide powder was present and they were not wearing a collar.

In order to be able to see just where the powder went, when it came in contact with the body of an insect wearing a collar, both borax and sodium fluoride were stained with either sodium carmine, or indigo carmine, after which they were thoroughly dried and pulverized to a powder. In a few cases, where dissections were to be made under water, Sudan III was used as the stain for the insecticide powder. Individual experiments were carried out with more than forty insects according to the outline just given, and all these were in agreement as to the question considered. It was found that powdered borax and powdered sodium fluoride could bring about the death of roaches through being dusted thoroughly on their bodies, without ever having come in contact with the mouth. The dusting of the body was done through the efforts of the insect itself, in scrambling and fluttering with the legs and wings in the manner already explained. Borax required two to ten days to cause death through contact of the powder alone. Sodium fluoride required from five to twenty-two hours. In each case the average time was much longer than was required to bring about death when the insect had eaten some of the powder in cleaning the same from its body. The symptoms following contact alone were usually very similar to those which followed when the poison had been eaten. As a rule, the period of partial paralysis and helplessness was much more prolonged when the powder had been used only as a contact insecticide. The exudation which caused the powder to stick to the roach's body was nearly always sufficient to dissolve enough of the borax or sodium fluoride to cause incrustation at the bases of the legs, between the sternal plates, etc.

In seventeen of the experiments in which the stained insecticide powder (sodium carmine was the stain mostly used) had been employed, the insects were dropped into a hot alcoholic fixing fluid at about the time of death. Afterward, parts of the bodies of these insects were embedded, and sectioned. A study was made of the miscroscopic sections prepared in this way, in order to learn by means of the stain if possible, whether the powder had entered the spiracles—or had passed, after solution, into the insect's body through the thinner portions of the body wall. The sections showed the incrustations of the stain at the bases of the legs, between the sternal plates, and (sometimes) just within the spiracles in the vestibule from which the tracheae arise; but no stain was found further within the tracheæ, and no sections were found which showed undoubted evidence that the stain had penetrated the integument to stain the hypodermal cells. If the cuticula was permeable to the stain and to the borax or sodium fluoride solutions in the same degree, then it is certain that only a very limited amount of the insecticide passed into the animal's body through the thinner portions of the body integument. The latter, however, seems to have been the possible and probable path. No indication was found that the stained insecticide powder had entered the bodies of cockroaches wearing the collars, in any other way. It must be remembered that the sodium fluoride rendered roaches helpless and practically dead in some cases within five hours—i. e., during the time the insects were wearing the collars, and sections showed no trace of stain in the crops of these insects. It took the borax so long to kill by contact that in the first tests, the roaches were brushed as clean as possible after six to eight hours treatment, and were then released from the collars. Proof was soon obtained that this would not do; the insects licked the joints of their legs and other rough parts of the body so thoroughly that the contents of the crop became decidedly stained. In other words, the insects did their cleaning so carefully that they might be eating enough of the borax powder to kill. The only safe method, therefore, was to leave the collars on the animals until they were no longer *able* to lick various parts of the body. That the death of an insect so treated was due primarily to the influence of borax powder brought in *contact* with the body, and not to injury from the collar (or otherwise) was shown by the checks carried out with untreated insects in collars, and by the absence of any stain in the digestive tract.

The evidence gained from the experiments carried out in this connection, therefore, may be summed up in the following statements:

When cockroaches run through powdered borax, sodium fluoride, or borax and pyrethrum mixed, the dry powder sticks to the legs, body, and often to the antennae. Some of the powder is moistened or dissolved in the exudation about the bases of the legs and on the thinner portions of the outer integument. This seems to cause some irritation and uneasiness; the insect soon begins to clean the moistened powder from the body by licking it. In doing this, enough of the poison may be brought into the mouth, and swallowed, to kill after a period varying from five hours to ten days. Borax acts much more slowly but kills with no less certainty than sodium fluoride. It is possible for both powdered borax and sodium fluoride to kill roaches by contact (without any of the poison's having been swallowed), but in actual practice it is hardly possible that any roach ever gets its body dusted with one of these powders without also licking and swallowing some of the powdered poison. Both powders are more rapid in their action as stomach poisons than they are as contact insecticides.

Tables IV and V contain representative results illustrating the influence of borax, sodium fluoride, pyrethrum and white hellebore on the reductases and catalases, respectively, of insect extract. Borax acted quite injuriously on the activity of the reductase, and very little on that of the catalase. The same was true of the hellebore and pyrethrum, except that the pyrethrum seemed to interfere a little more with the activity of the catalase than did either the borax or the hellebore. Sodium fluoride was most detrimental to the catalase. When added to perfectly fresh extract, the sodium fluoride caused a slight drop in reductase activity; after that however, such a treated extract retained its reductase activity very much better than did untreated extract. Both sodium fluoride and borax interfered with the oxidase activity slightly, if one may regard the alcoholic guaiac test as an indicator in this case.

An attempt was made to determine the influence of borax and sodium fluoride upon the respiratory ratio of cockroaches dying under the influence of these poisons, but the normal respiratory ratio, itself, varied so much for the roaches that no decided information could be gained. The intestinal tracts of the specimens used were apt to be gaseous, and the contents of the intestines were usually found to be well infested with infusoria, etc. This, it was believed, might account for the normally irregular respiratory ratio.

SUGGESTIONS FOR POSSIBLE PRACTICE.

(a) SOLID AND LIQUID APPLICATIONS.

It will be observed that when the insecticides gained entrance into the insect tissues as purely contact agents, they did so, ultimately, in the fluid condition. Powdered solid contact insecticides gave off volatile bodies to be absorbed by the insect, or else the powdered agent became moistened and partly dissolved in exudations on the insect integument. Experiments showed that gases or volatile insecticides gained entrance to the insect tissues most rapidly. The "miscible oils" usually combined volatile and purely liquid agents. The liquid or the finely powdered solid often gained entrance through the spiracles to the larger tracheae where any volatile bodies that might be carried by the insecticides could then charge the air of the tracheal system. In the case of the powdered solid contact insecticide, the advantage evidentally lay in having the powder so fine and dry that it would adhere well and could sift readily into all crevices—even into the stigmata of the insect. Similarly, a weak surface tension for a liquid insecticide enabled it to flow into all irregularities of the area treated, and to penetrate often into the larger tracheae of the insect. Even in the case of lime-sulphur wash—which kills scales, perhaps in most cases, without ever having actually come in contact with the body of the insect itself—it would seem to be advantageous if the wash could be given a lower surface tension. The solution could then flow into crevices of the bark and thoroughly wet the scale-covering of insects that might otherwise escape. As is well known, soap cannot be used for the purpose, since it causes in the lime-sulphur solution a greasy lime-soap precipitate. A number of tests were carried out with the idea of finding agents which might be added to lime-sulphur, without injury, to lower the surface tension and cause it to spread on the bark of plants more readily. In order to be able to compare the "spread" of different samples of lime-sulphur dilutions readily in the laboratory, resort was had to what may be termed the "drop method." For example, the number of drops in 5 c. c. of water were counted as they came from a pipette. The same pipette was then washed out with lime-sulphur prepared by diluting a concentrate with a water solution of the agent to be tested. The number of drops in 5 c. c. of the latter lime-sulphur dilution were then counted from the pipette, and the ratio of the number of drops of water to the number of drops of lime-sulphur dilution was obtained. As long as the temperature of the liquids was practically the same and the drops were counted from the same cleaned pipette, the ratio between the number of drops in equal volumes of water and *any* lime-sulphur dilutions of approximately equal densities afforded a direct means for comparison of spread in the various dilutions. Actual trial on a tree covered with scale insects, showed that when this ratio equalled about 0.85[*], the "Agent plus L. S. solution" had sufficient spread; that is, the spray readily flowed into crevices of the bark and wet the waxen scale coverings. The method was adapted from

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[*] (e. g. $\frac{\text{Number drops in 5 c. c. of water}}{\text{Number drops in 5 c. c. of ``Saponin-water-dilution of Conc. L. S.''}} = 0.85$.)

Mansier† who first suggested counting the drops in equal volumes of liquids under proper conditions of temperature, etc., for making a study of their surface tension in connection with insecticides. It was found that gelatine, glue, soluble albumen, and saponin could all be used in lime-surphur to increase the "spread" on the bark of a tree. The various agents were dissolved in the proper amount of warm water, after which the solution was added to concentrated lime-sulphur in making up the proper dilution. Glue and gelatine had to be used at the rate of about one pound to eleven gallons of lime-sulphur wash as diluted ready for use. The expense, therefore, would be too great to make their employment practical. This was true also in the case of albumen and saponin. Except for its expense, however, saponin seemed to be best of all the agents tried for the purpose. It dissolved readily, and a comparatively small amount added to the lime-sulphur increased the "spread" to the desired point without any apparent injury to the oxygen-absorbing power of the wash. Tests were made of this last point in the following manner:

A measured amount of the solution of saponin in water was added to a measured amount of concentrated lime-sulphur in a stender dish of standard volume and diameter; then, an equal sample of the same concentrated lime-sulphur, in a dish of the same diameter, was diluted with a volume of distilled water equal to the saponin solution used. The two dishes were introduced into exactly similar containers with equal volumes of air having the same known percentage of oxygen. At the end of a certain period of time (6 hours, for example) the oxygen percentage in each air-chamber was again determined, and from that, the volume of oxygen that had been absorbed. The volumes of oxygen absorbed in the saponin-lime-sulphur and in the check were practically the same—the greatest difference in three successive tests being no greater than the possible experimental error of the apparatus. When the dry powder was stirred directly into the lime-sulphur, however, the oxygen-absorbing ability of the solution was quite appreciably weakened. This was due no doubt to oxidation of the sulphides by air carried in with the dry powder. It was best, therefore, to dissolve the saponin in water, and then add that solution to the concentrated lime-sulphur.

Four tests were carried out to determine the influence of adding saponin, upon the rate at which water would evaporate from lime-sulphur (i. e. influence upon rate of drying). In every case, the evaporation was found to be a little more rapid from the lime-sulphur to which saponin had been added—as might be expected from the weakened surface tension. The difference, however, was not great—amounting to only 0.1 grm. of water from an area of 10.17 cm. in seven hours, on the average. This difference could be largely eliminated by adding salt (Na Cl) to the saponin-lime-sulphur solution. That is, salt had the effect of retarding the evaporation of water. It was used at about the rate first recommended in the original lime-sulphur salt-wash (i. e. about 18 lbs. to 100 gallons). Except in extremely dry weather or in a normally dry climate the salt would not serve a useful purpose.

Finally, all the tests tried seemed to confirm the first impression that saponin would be the ideal agent for lowering the surface tension of lime-sulphur to obtain "spread," if only it were not so expensive. At the price of crude saponin, when these tests were carried out, it would add about $1.50 to the expense of each fifty-five gallons of lime-sulphur wash diluted ready for use against San Jose scale. The crude saponin, however, was just as good for the purpose as the *pure* obtained from Merck at a cost of more than five times the price of the crude product. Now the dry plant, *Saponaria officinalis* or "*bouncing bet*" was known to contain from thirty to forty per cent of extractives and it occurred to the author that perhaps the plant, itself, could be used in this connection. *Bouncing bet* grows about many farm yards, orchards, or gardens, coming up year after year from underground stolons. It is quite hardy, escaping cultivation and growing by roadsides, often, quite thickly. If the *plant* could be used, therefore, the orchardist might have a plot planted to *bouncing bet*, and prepare his lime-sulphur-saponin wash with only the extra expense of cutting, storing and extracting—which need not be great, it was thought. Accordingly, some plants were cut and dried in the early fall and laboratory experiments were carried out to determine whether "bouncing bet hay" could be used to satisfactorily increase the spread of lime-sulphur wash. Stated briefly, results proved that an excellent lime-sulphur spray mixture, as regards spread, etc., could be obtained by the use of an extract of either the green or the dry stems and leaves of *bouncing bet*. A good method of extraction was as follows:—the plant material was soaked in lime-water over night (12 to 18 hours, say) after which it was boiled about 30 minutes and then pressed out and strained. Thus an extract was prepared by using the dry stems and leaves of *bouncing bet* at the rate of 22lbs. of the plant material and 15lbs.* of freshly slacked lime to 50 gallons of water. This extract could be used to dilute concentrated lime-sulphur (of 26° Baume' and up) the required amount for use against San Jose scale; giving the spray mixture a very satisfactory spread. The added lime in the extract should prove useful, also, in assisting the lime-sulphur to soften the wax about the margins of the scale-coverings—in addition to the fact that it serves as a first class marker to show whether all parts of a tree have been covered.

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†Mansier, M., 15 Jan. 1908, Bulletin de la Société des Agr. de France.

When extract water from *bouncing bet*, prepared as explained above, was used in the place of ordinary water in the old formula (lump lime 20 lbs., sulphur flour 15 lbs., water 50 gallons) a homemade wash having a very high degree of spread resulted. A little of such a homemade wash was filtered, and the number of drops in 5 c. c. of water divided by the number of drops in 5 c. c. of the filtrate equalled 0.72. One homemade lot of lime-sulphur was prepared (in a smaller amount than is called for by the formula) while the plant material was still in the water. The formula follows: lime 20 lbs., sulphur 15 lbs., water 50 gallons, and 22 lbs. of the dry leaves and stems of *bouncing bet* to which enough water to wet them thoroughly had first been added. The mixture was kept boiling for forty-five minutes, after which the liquid was pressed out, and strained through coarse cheese cloth. The lime-sulphur appeared to have cooked up in good shape and the "drop ratio" for the spray solution was 0.73.

Whether these suggestions would actually prove profitable in orchard practice may be learned only by experience. If they should prove to be so, it is likely that commercial companies might produce a crude extract of *bouncing bet*—incorporating it in lime-sulphur concentrate, cheaply. A single test extending over several months indicated that saponin, in itself, did not cause lime-sulphur to deteriorate.

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*Less lime may be used. It is not absolutely necessary but it assists in softening and digesting the plant and in other ways.

b. FUMIGANTS.

The advantage of the fumigant—i. e. vapor or gaseous—contact insecticides are generally recognized. Likewise, disadvantages are equally well known. Generally speaking, gases diffuse rapidly and often penetrate where non-volatile liquids could never penetrate without damage—as in stored grain, clothing, etc. Also many gases or vapors are more rapidly absorbed by active insects than are any non-volatile liquid insecticides. A disadvantage, such as difficulty of confining a gas for the necessary period of time, may be overcome; but danger from fire and explosion in the case of carbon disulphide, and difficulty of application because of its danger to the operator in the case of hydrocyanic acid gas are disadvantages never entirely eliminated. It was in the hope of finding fumigants which might be safely substituted, in some cases, for the two fumigant insecticides just named that test work was carried on with ammonia and carbon tetra-chloride.

Ammonia. Experience gained with ammonia as an insecticide, during the time its influence upon the respiration of insects was being studied, led to the belief that perhaps ammonia gas from compressed or liquified ammonia might be applied as an insect fumigant with greater ease and with less danger than hydrocyanic acid gas. Experiments carried out with *Calandra granaria*, *Silvanus surinamensis*, and larvæ of *Tenebroides mauritanicus* enclosed with a little dry wheat in tight glass receptacles showed that the insects could *all* be killed with three to four per cent ammonia in twenty to twenty-two hours, and with nine to ten per cent in six to seven hours. In fact, it was possible to kill in most cases at lower percentages, and in shorter periods when using the higher percentages of ammonia—but death was always certain when the gas was used at the rates given.

A few germination tests were made with dry wheat treated with different percentages of ammonia, 100 grains being used in each check and in each treated sample. It was found that where the percentage of ammonia was kept up to about 3.2 for 22 hours the germination was ruined. At 10 to 13.5 per cent for an interval of eight hours, however, the per cent of injury from ammonia to germination was less than one; for ten hours at 11.9 per cent the injury was over fifty per cent.

Following the various laboratory tests, two fumigations of the college mill-room were carried out with ammonia gas derived from cylinders of compressed and partly liquefied ammonia. The room was closed as tightly as any plastered room with closely fitting windows may be closed. The iron tube of ammonia was placed on a platform balance outside, and the ammonia gas was conducted through a tube (properly fitted under the door) almost to the center of the room. Two wire cages of insects were left in the open where they could be seen from the outside through the glass of the mill-room door. Two other cages were buried three and six inches, respectively, in dry wheat. There were about fifteen bushels of sacked wheat, and a little corn in the ear, stored in the room. In the first test (Oct. 7, 1911) ten pounds of ammonia were passed through the tube. Since the air-space where the gas expanded was 7166 cubic feet, the percentage of ammonia was about 3.1 in the early part of the test. The experiment ran between nineteen and twenty hours. A caged specimen of the large American cockroach was still alive at the end of the test, but he was so under the influence of ammonia that he died from the effects later. *S. surinamensis* and *C. granaria* in one of the exposed cages were motionless. Some of the *Calandra* recovered in fresh air enough to move their legs, but none ever recovered entirely. All the beetles in the two cages buried in the wheat were active at the end of the test and were still alive and normal three days later. The next day living specimens of the saw-tooth grain beetle were found between the grains of the corn in the ear.

On November 21, 1911, the mill was again fumigated with ammonia in the same manner as in the first test; but this time 32.5 lbs. of the compressed ammonia were used—i. e., one pound of ammonia gas to 223.9 cubic feet of air space. This gave about ten per cent of ammonia in the room. One hour and fifteen minutes were used in introducing the charge, and the room was kept closed (over night) for seventeen hours. Wire-caged insects had been introduced again, as well as several large sacks of infested wheat. About twenty bushels of new corn that was not very dry was present also. The latter became very decidedly darkened during the test. Wheat was always more or less darkened by ammonia fumigation in the laboratory tests—as well as in the mill test—but the dryer the grain, the less noticeable was the darkening in every case. In this test, a caged cockroach (*P. americana*) became quiet by the time the charge had been two-thirds introduced. The roach was dead at the end of the test, as were also the caged beetles left in the open. Mice were killed. One mouse was seen to come out on the floor and die when fumigation had been going for forty-five minutes. Insects about one inch deep in the wheat were killed, but caged beetles (saw-tooth grain beetle and grain weevil) buried in the center of a sack of wheat were active at the end of the test. In both the mill tests brass and copper parts of the mill machinery were covered with vaseline, which protected them perfectly from action by the ammonia. The compressed ammonia was certainly convenient to apply; and at three to four per cent, fumigation could be carried on with the gas at a reasonable cost, since iron cylinders of liquefied ammonia could be obtained at that time for twenty-nine cents per pound. Considerable of the ammonia was absorbed by the grain; but after a few hours airing, the odor disappeared. The darkening of the grain seemed to be an undesirable feature, however. Mr. Spragg of the Farm Crops Department prepared flour from three kinds of wheat treated in the first mill experiment—and also, from the three corresponding check samples of wheat. There was no taste of ammonia on any of the flour, but that from two of the treated samples of wheat was quite noticeably darker than the corresponding checks. A Lansing miller, who was kind enough to slick the samples of flour and judge them, decided that the action of the ammonia on the wheat had undoubtedly injured its milling qualities commercially. To be sure, the grain was really darkened, noticeably, to a depth of only two or three inches in a large container; but at that depth, the insects were not killed. For the reason just stated the mill experiments with ammonia were discouraging—although it appeared that the gas, in some instances, might prove to be a desirable fumigant for insects.

Carbon Tetrachloride. Early in the year 1910, Professor Pettit was urged in behalf of the Michigan Millers to find, if possible, some volatile non-inflamable liquid which might take the place of carbon disulphide as a fumigant for grain in bins. It was suggested to him by Professor Kedzie of the Chemistry department that perhaps carbon tetrachloride might have the qualities desired. Following this suggestion, a series of comparative tests with carbon disulphide and carbon tetrachloride were carried out by Professor Pettit, Mr. M. A. Yothers (who was connected with the department at that time), and the writer, working together. The tests were made in large glass flasks with rubber stoppers. Among the insects in the infested grain used in these tests were the following beetles determined by Prof. F. H. Chittenden of the U. S. Bureau of Entomology:

Rhizopertha dominica,
Latheticus oryzæ.
Laemophlaeus pusillus,
Calandra oryzæ,
Tribolium ferrugineum.

A great many *Silvanus surinamensis* were also used. In these tests carried out in the tight glass flasks, practically all beetles were killed by carbon disulphide used at the rate of ¼ dram to a cubic foot of air space. It took 1½ drams of the tetrachloride of carbon to accomplish the same result (at about 70° F.). That is, compared with carbon disulphide, six times as much carbon tetrachloride was required to accomplish effective fumigation. The tests were run from seventeen to twenty-four hours. It should be stated that the liquid insecticide in every case was dropped upon a thin piece of absorbent cotton, which was suspended at the center of the flask. Thus, the broad surface of the cotton enabled the fluid to evaporate rapidly. The liquid carbon tetrachloride was found to be entirely non-inflammable—and its vapor, non-explosive.

Results of the experiments just described were not published at the time—mainly because the expense for effective fumigation with carbon tetrachloride seemed so great as to be almost prohibitive. Dr. Britton of the Connecticut Experiment Station had given, in 1908, his experiments with carbon tetrachloride used as a fumigant against scale insects on nursery trees.*

Later, Feb., 1910, Mr. Albert P. Morse published a note on "Carbon Tetrachloride vs. Carbon Bisulphid" as a fumigant used in the control of grain and natural history pests.† Mr. Morse stated that "for large cases a strength of one quart to fifty cubic feet is desirable—practically twice that of carbon bisulphid, of which a pint to fifty cubic feet is sufficent."

In October, 1911, Professor F. H. Chittenden and Mr. C. H. Popenoe of the U. S. Department of Agriculture published a paper on experiments carried out with the same chemical used as a substitute for car-

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*Journal of Economic Entomology, Vol. 1, No. 2, p. 111.
†Journal of Economic Entomology Vol. 3, No. 1, p. 104.

bon bisulphid in fumigation against insects.* The authors found that "if the material were a cheap product, it might prove a substitute for carbon bisulphid if used in strength greater than ten pounds to one thousand cubic feet."

Later still (May, 1913), Professor H. Garman of the Kentucky station stated that, as the largest amount of carbon tetrachloride used in a series of tests, 20.8 ozs. to 100 cubic feet killed 100 per cent of the insects in nine cases out of twelve.†

In the Spring of 1914, a request came from the J. W. Knapp Department Store of Lansing, Michigan, asking for some safe means of insuring valuable furs, stored in a small room, against moths during the summer. The "fur room" was 4x6½x6½ feet—the side walls tightly built of matched lumber, the ceiling of glass. It was located in the large cloak and coat department room, where it was very accessible; but any fumigant used had to be as inoffensive as possible, without especial danger to human life, and without the entailment of extra fire risk. Carbon tetrachloride suggested itself as the possible, satisfactory fumigant in this case. Further laboratory tests had shown the writer that with ordinary wooden enclosures, which were not practically gas-tight (as was the case with the glass flasks), perfect fumigation could not be obtained at usual room temperatures (68° to 70° F), even when the carbon tetrachloride was exposed in a wide vessel. The vapor slowly escaped from the walls of such enclosures, and evaporation did not go on rapidly enough at even 70° F. to bring about the necessary concentration for perfect fumigation. It was necessary to use heat and vaporize the liquid quickly. Dr. Britton had experienced a somewhat similar difficulty in volatilizing this liquid in his experiments with nursery stock. He finally resorted to the use of heated cast iron pans for generating the vapor more quickly (citation given above). Recommendation was made in this instance, therefore, that six pounds of carbon tetrachloride be vaporized from wide, heated pans placed near the ceiling of the "fur room"—and that the charge be started immediately after closing hours in the evening. According to this recommendation, the liquid carbon tetrachloride was used at the rate of about 3.55 pounds to 100 cubic feet of room space. Heat for vaporization was supplied by hot, flat soapstones laid on iron brackets. The wide pans of carbon tetrachloride were set on the hot soapstones and the room was quickly closed. In the case of the first charge tried, the stones had not been made hot enough and not quite all the liquid insecticide had evaporated even after twenty-four hours. Several adult moths (*Tinea biselliella*) had been placed in a wire cage in the room. These were quiet when the cage was removed at the end of the twenty-four hours period, but after about four hours in fresh air two moths recovered enough to be able to move their legs. However, none ever recovered entirely. Another charge was made with six pounds of the carbon tetrachloride, and this time the soapstones were made very hot so that the liquid vaporized rapidly. A cage of moths could be observed through the glass roof of the room. They quickly became quiet. Before morning all the liquid insecticide had been vaporized. The cage was removed after thirty-six hours, and the moths were

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*Bulletin No. 96, Part IV, 1911; Bureau of Entomology, U. S. Dept. of Agriculture.
†Kentucky Sta. Bulletin No. 172, p. 200.

kept under observation at intervals for one day; none of the insects showed any recovery. (See tables IV and V for the effect of carbon tetrachloride upon reductases and catalases). This last charge of insecticide vapor was considered satisfactory; and following it, similar fumigations were made at intervals of about five weeks, on the average, from May until October. The large room, in which the "fur room" was located, was well ventilated and nothing of a disagreeable nature was ever experienced from the fumigation. All the furs came through the Summer in fine condition. The company management was so well pleased that the same method is being used with the furs again in the Summer of 1915. Moreover, Mr. Armstrong, who was in charge, reported that this method of caring for the furs had proven to be cheaper than 'cold storage"; and in addition, it afforded the very great advantage of convenience in having the furs where they were easily accessible. Carbon tetrachloride cost the company twenty-seven cents per pound.

C. HEAT AS AN INSECTICIDE.

Finally, suggestions relating to possible practice should certainly call attention to heat as an insecticide. The effect of heat upon oxidases, catalases and reductases in the tissues of *P. cornutus* and various other insects has already been given earlier in this paper. No more efficient means than heat was found for destroying the activities of these three agencies of the tissue cells; it was shown that when specimens of *P. cornutus* were killed by the least degree of heat that could be effectively used, the activities of reductases, oxidases, and catalases were injured in a greater or less degree. The effect of different degrees of heat in coagulating the various soluble proteins in animal tissues is well known. It should be added here that fatal injury to the insects, and noticeable injury to one or more of the three kinds of enzyme-like bodies named, seemed to occur just before the first agglutination of protein took place. The reductase was the most susceptible. In case of clear, filtered water extracts of the tissues of *P. cornutus*, which were heated up very slowly and gradually, the soluble catalase showed its greatest loss in activity earlier than the guaiac oxidase. The latter lost its principal activity at the moment of separation of the chief or largest protein precipitate.

The fatal temperature, in the case of insects, varied considerably with the species and with the length of time the insects were exposed. No insects were tried, however (in small enclosures), which required a temperature of more than 122° F. maintained for a period of three hours to cause death; and at that temperature, death usually resulted quickly. Now, 122° F. is a comparatively low temperature and many plants can stand exposure to even higher temperatures for several minutes without appreciable injury. It is very well known that cabbage can endure hot water or hot soapsuds much better than can the common "cabbage worm." In fact, when cabbage is heading, hardly any safer or better method for killing cabbage-worms in the home garden is practiced than the use of hot soapsuds. During the last five or six years, Professor Dean of the Kansas State Agricultural College and Experiment Station has introduced heat as a comparatively cheap and efficient method of controlling all classes of mill-infesting insects.* The method has been put to the test in several other states and is now recognized as the best method of controlling insects in well built, steam-heated mills.

In view of the above facts it has seemed to the author that perhaps heat might be applied to advantage as an insecticide for many insects in situations where it has never been the practice to use it. A few, more specific suggestions may be made. There have never been any extensive tests carried out (so far as we have been able to find) to determine whether heat might not be used profitably in certain instances to clean some kinds of nursery stock of insect pests. One opportunity was afforded the author of making a limited test of the possibilities along this line. Forty-four one year old apple-stocks were given by the Department of Horticulture for the test. It had been found by trial that San Jose scale on thickly infested twigs could be killed by submerging them for five minutes in water heated to 130° F. The green apple aphis was killed within one-half minute in water at that temperature. The test with the apple-stocks was carried out, therefore, to learn something of the effect, upon the stocks themselves, of dipping them in water at certain temperatures for different periods of time. The bundle of stocks, wrapped in sphagnum, had been kept all winter in the basement of the cold storage plant at the College. They were still almost entirely dormant on May 4th, 1914, when the test was started. Ten average stocks were picked out for a check—not to be treated, but planted just as they came from the storage. The remainder were given treatment as follows:—

(1) 5 stocks—tops, only, dipped at 130° F. for 5 mins.
(2) 5 stocks—tops, only, dipped at 130° F. for 10 mins.
(3) 5 stocks—tops and roots dipped at 130° F. for 6 mins.
(4) 5 stocks—tops, only, dipped at 140° F. for 5 mins.
(5) 5 stocks—tops, only, dipped at 140° F. for 15 mins.
(6) 5 stocks—tops and roots dipped at 140° F. for 20 mins.
(7) 4 stocks—tops and roots dipped at 150° F. for 10 minutes.

All the stocks were then planted in a row close together at the same depth in the same kind of soil.

The checks or untreated stocks leaved out several days ahead of the treated plants, but all of the latter finally came into leaf, and were still alive in the fall—except the four stocks which had been treated in water at 150° F. for 10 minutes. Those four plants had been killed, evidently by the treatment. Examined on May 21, 1915, most of the young apple trees were in almost full leaf. The dead and injured trees could be easily recognized. Nine of the trees in the check were alive and one dead. By numbers, the condition of the treated trees was as follows:—

(1) 5 trees alive.
(2) 4 trees alive; 1 tree dead.
(3) 3 trees alive; 2 trees dead.
(4) 3 trees alive; 2 trees dead.
(5) 5 trees alive; 3 of them with 3 or 4 inches of stock dead at the top.

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*Bulletin No. 189, 1913, Kansas Agr. Expt. Station.

(6) 2 trees alive; 3 trees dead.

(7) These trees were all dead last Fall.

It will be observed that some of these plants stood exposure to a higher temperature for a longer period than would be necessary to kill San Jose scale. This test is not offered as in any way conclusive, however. It is described here in order to better call attention to the suggestion that possibly a careful and thorough investigation along this and similar lines might be worth while.

Most household pests succumb readily to heat. For example, adults of one of the common clothes-mothes (*Tinea biselliella*) may be quickly killed at 119° F. A hot flat iron has often been recommended as a means of killing the larvæ of moths in clothing—but might not some practical and safe means of applying heat be arranged to insure valuable clothing in chests or closets against moths? Thus, there are many possibilities for heat, as an insecticide, that have never been carefully and systematically tested as to their larger practicability.

GENERAL CONCLUSIONS.

Reductases, catalases and oxidases were found in water extracts and in the insoluble pulp of the tissues of *P. Cornutus* and other insects. Moreover, almost certain evidence indicated that the same three kinds of enzyme-like bodies exist in the intact tissues of living insects.

Heat of certain intensities, and the several contact insecticides studied (gasoline, carbon-disulphide, hydrocyanic acid gas, sodium fluoride, etc.), when used at a concentration sufficient to kill insects, deleteriously affected the activities of reductases, catalases and oxidases—usually in unequal degree, thus disturbing the natural or normal balance of such activities.

If the catalase, oxidase, and reductase activities are actually of as vital importance to the life processes of the tissue cells as certain evidence indicated, then the deleterious action of the contact insecticides studied in this connection must be an important factor—perhaps, in some cases, the *determining* factor—in causing the death of treated insects.

A study of the influence of the various contact insecticides upon the life processes in nervous tissue cells seems of next importance in this connection.

Fat or fat-like membrances (e. g., lard and lanoline) absorbed gasoline-vapor (and chloroform-vapor) from air charged with that vapor, and the absorbed vapor rendered the membranes less permeable to oxygen. This finding may, in part, account for the fact that less oxygen was used by an insect deeply under the influence of gasoline, since a similar condition existed—in that, under such circumstances, the lipoids of the living, oxygen-absorbing cells, and of the body fluids surrounding them, were impregnated with gasoline. So also, the same finding may help to explain the fact that, in the presence of air containing gasoline vapor, less hydroquinone was oxidized in an "insect tissue extract plus hydroquinone solution" (in which the reductase had mostly passed) than was the case when the same extract was in pure air.

Waxen membranes which had been thoroughly wet with lime-sulphur solution were found to be less permeable to oxygen than before they were treated with the solution. Thus lime-sulphur, in addition to its effect as described in a former paper, would render the waxen covering of a scale insect less permeable to oxygen.

Pupæ of the Luna moth, and adults of *Passalus cornutus* in a dormant condition from cold, absorbed much less gasoline-vapor or vapor of ether in air than did the same insects when they were most active, at a warm room temperature, in air charged with practically the same percentage of vapor. This lowered absorption capacity, which was found to accompany the dormant condition, may furnish the chief explanation of the fact that insects, dormant from cold, are harder to kill by ordinary fumigants and by those contact sprays which depend partly upon volatile insecticide ingredients for their effectiveness.

It was found that certain non-volatile, powdered solids were able to act as effective contact insecticides when used on certain insects. Such dry, powdered insecticides stuck fast in exudations on portions of the insect body, where they became partly dissolved, after which they appeared to be slowly absorbed through the body-integument.

Both powdered borax and sodium fluoride may kill cockroaches in the manner of purely contact agents, but normally they become stomach poisons as well—since the roaches regularly lick and swallow some of the powder in cleaning it from their bodies.

In the case of powdered solid contact insecticides, the advantage seemed to lie in having the powder so fine and dry that it could sift readily into all crevices and could adhere well. Similarly, other things being equal, a weak surface tension gave a liquid contact insecticide an advantage, enabling it to thoroughly wet the bodies of insects and to flow into all irregularities of the area treated.

Among several substances which were found to increase the "spread" of lime-sulphur solution, saponin or extracts taken directly from the stems and leaves of *Saponaria officinalis* (*bouncing bet*) seemed to be best. It is suggested that perhaps the use of extracts from "bouncing-bet hay" with lime-sulphur solution might prove profitable in orchard spray-practice.

Experiments with ammonia (derived from dry liquefied ammonia) as a fumigant for mill insects were rather disappointing; but the liquified ammonia was easy to apply and might prove to be a desirable fumigant for insects in some instances.

When carbon tetrachloride was compared with carbon disulphide as to its action on grain insects in tight flasks, six times as much of the former was required for effective fumigation. The carbon tetrachloride was vaporized with heat and satisfactorily used, at the rate of 3.55 lbs. for 100 cubic feet of air space, to insure furs against moths—fumigation being repeated every five weeks during the summer months. The charge as used killed adults of *Tinea bisselliella.*

Evidence indicates that heat might be applied to advantage as an insecticide in many situations where it has never been the practice to use it.

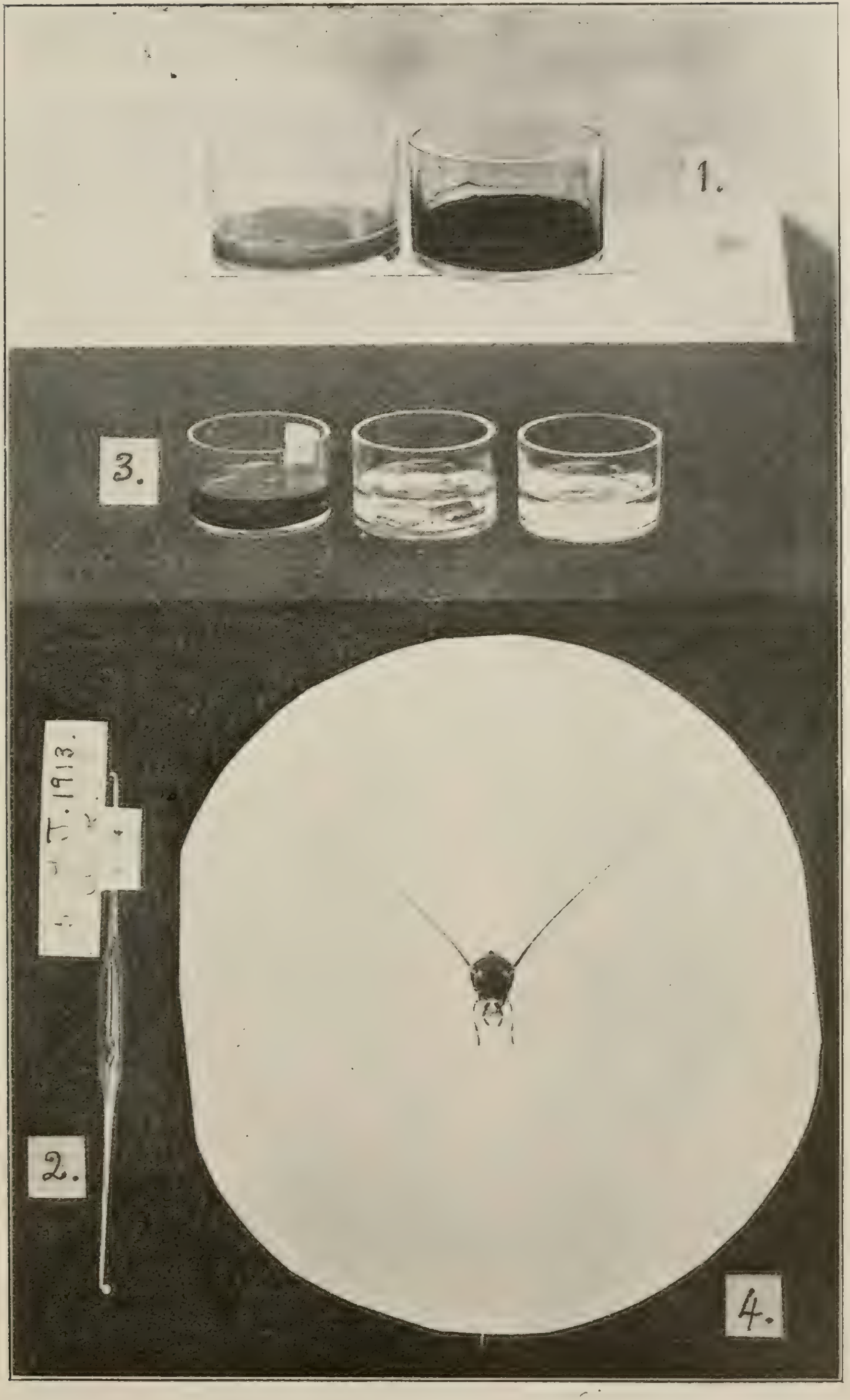
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PLATE I.

Fig. 1. Sample of thick creamy extract in the left stender dish was treated strongly with CS_2 and $\frac{M}{10}$ hydroquinone was added later in the presence of the CS_2.

Check extract to the right (not treated) had the same amount of $\frac{M}{10}$ hydroquinone added, at the same time as the treated extract.

The darker color of the check shows the greater oxidation of the hydroquinone to quinone.

Fig. 2. Shows the form of sealed tube in which the reducing action of insect-tissue extract toward methylene blue, indigo carmine, etc., was studied.

Fig. 3. First cup to the left shows the darkened solution of tyrosin, oxidized under the influence of a crushed elytra (thoroughly cleaned with alcohol) of an old adult *P. cornutus*.

Middle cup contains clear unoxidized solution of tyrosin with crushed elytra which had been heated to boiling for 10 minutes.

Cup to the right—check, containing only tyrosin solution which remained clear during the 7 days of the test.

Fig. 4. Cockroach (*P. americana*), showing the head and arrangement of the white bristol-board collar to prevent the insecticide powder, with which the body was treated, from reaching the insect's mouth.

EFFECT OF TEMPERATURE ON THE MOVEMENT OF WATER VAPOR AND CAPILLARY MOISTURE IN SOILS.

Technical Bulletin No. 22.

MOVEMENT OF MOISTURE FROM WARM TO COLD COLUMN OF SOIL OF UNIFORM MOISTURE CONTENT.

The surface tension and viscosity of water decrease with rise in temperature to the extent shown by the data in table 1.

TABLE 1.—RELATION OF TEMPERATURE TO THE SURFACE TENSION AND VISCOSITY OF WATER.

Temperature C°.	Surface tension.	Viscosity.
0	100.	100.
10	97.96	73.32
20	94.32	56.70
30	91.62	45.12
40	88.46	36.96
50	85.52	30.17

It will be noted that the degree of diminution with rise in temperature is considerably greater in the case of viscosity than in surface tension.

During the warm part of the year the soil at the upper depths maintains a rather marked temperature gradient which reverses itself between day and night to the depth that the diurnal amplitude of temperature oscillation extends. This diurnal change of temperature gradient occasions an alteration in surface tension and viscosity of the soil moisture, the amount depending upon its variation at the different depths. Since capillary action is said to depend upon surface tension, and facility of movement upon viscosity, then there should occur an upward and downward movement of moisture as the temperature gradient changes diurnally. During the day, for example, the temperature of the soil is highest at the surface and diminishes with depth; the surface tension and the viscosity of soil moisture, are lowest at the surface and rise with depth; consequently the movement of moisture should be downward. During the night, the reverse is true; the soil temperature is lowest at the surface and increases with depth; the surface tension and the viscosity of the soil water are greatest at the top and diminish downward with increase of temperature; hence, the water translocation should be upward.

These considerations are *a priori* deductions from the laws of surface tension and viscosity in their relation to temperature. Whether or not they are valid, however, is heretofore not known; since there appear to be no experimental data bearing directly upon the subject.

With the object in view of ascertaining this important and much desired information an investigation of the problem was undertaken. The general method of procedure consisted of placing soil of different but uniform moisture content in brass tubes 8 inches long and 1½ inches in diameter, closing both ends with solid rubber stoppers, and keeping one-half of the soil column at a high temperature and the other half at a low temperature for a certain length of time, then determining the percentage of moisture of the two columns, and attributing any difference in water content to thermal translocation. There were only two amplitudes of temperature employed, 0° to 20° C., and 0° to 40° C., i. e., one-half of the soil column was kept at 0° C. and the other half at 20° and 40° C. For producing these temperature amplitudes wooden boxes were used which contained melting ice and warm water separately and their temperatures were maintained constant by the addition of ice and hot water respectively.

The movement of moisture from warm to cold soil was studied in two different ways: (1) when the column of soil stood horizontally, and (2) when it stood vertically. For the first case, the wooden boxes used were 22 inches long, 10 inches wide, and 20 inches deep, having a wooden partition in the center which contained perforations of the size to fit the tubes. One compartment contained melting ice and the other water at the desired temperature. To prevent any exchange of water between the two compartments the edges of the partition and the holes through which the tubes passed were made water-tight by means of paraffin. For the second study, the employment of two boxes was necessary. One box, which contained melting ice, was 24 inches long, 10 inches wide, and 13 inches deep. The other box, which contained water at the desired temperature, was made to fit the inner side of the first box and was 13 inches long, 7 inches wide and 11 inches deep. The bottom of the small box was supplied with holes in which to place the tubes. The size of the perforations was made to fit the tubes tightly. To make the small box also water proof the crevices surrounding the tubes were sealed with melted paraffin. The small box was then put upon supports in the large box. The latter was filled with melting ice up to and touching the bottom of the former. The water in the upper box was kept at the desired temperature. A diagram of both set of boxes is shown in figure 1. All the boxes were well insulated, and since they were big and contained large volumes of water the temperature could be kept to within small variations for long time. The water was stirred occasionally, to maintain uniformity of temperature throughout the mass.

The temperature amplitudes employed are within the upper limit of the diurnal amplitudes of temperature at the upper depths in the soil but they are too high for the range of temperature that exists at any one time between the various adjacent depths.

The duration of each experiment was about eight hours. This time limit was calculated to represent approximately the length of time that the day and night soil temperature gradient is most marked.

The effect of temperature on the movement of moisture in soils of uniform moisture content was investigated in 5 diverse classes of soil, namely: Miami light sandy loam, Miami heavy sandy loam, Miami silt loam, Clyde silt loam and Miami clay. Each soil contained a large number of different moisture contents. These various moisture contents in each soil ranged from very low to very high.

To procure very uniform moisture content throughout the soil column each soil, after it was moistened to the desired degree, was passed through

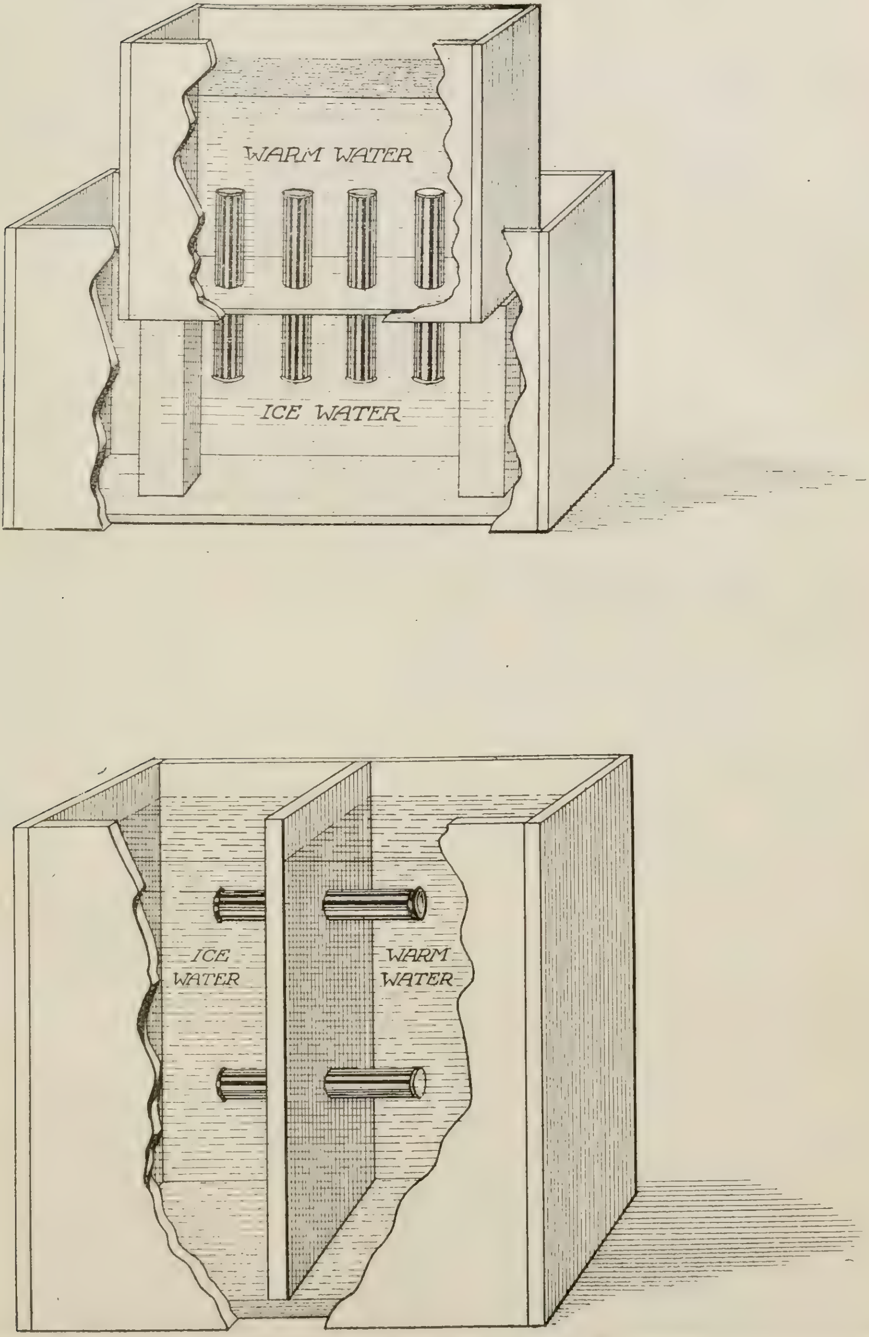

FIG. 1. APPARATUS FOR MEASURING THE THERMAL MOVEMENT OF MOISTURE IN SOILS EITHER VERTICALLY OR HORIZONTALLY.

TABLE 2.—PERCENTAGE OF MOISTURE MOVED FROM WARM TO COLD COLUMN OF SOIL OF UNIFORM MOISTURE CONTENT.

Kind of soil.	Percentage of moisture.									
Sandy loam:										
Beginning of experiment	2.29	3.86	6.45	7.50	8.48	9.95	10.94	13.75	15.96	....
Movement from 20 to 0°C	0.102	0.296	0.792	0.900	0.530	0.520	0.466	0.340	0.100	....
Movement from 40 to 0°C	0.410	1.064	1.97	2.882	1.715	1.467	1.30	0.97	0.30	....
Heavy sandy loam:										
Beginning of experiment	4.20	6.52	9.08	10.42	12.43	14.02	16.03	....	....	....
Movement from 20 to 0°C	0.160	0.631	0.930	0.721	0.582	0.491	0.21	....	....	....
Movement from 40 to 0°C	0.59	1.75	3.02	2.40	1.98	1.40	0.42	....	....	....
Silt loam:										
Beginning of experiment	4.29	8.06	9.76	11.28	14.441	15.95	17.63	19.30	21.42	23.51
Movement from 20 to 0°C	0.138	0.736	1.024	1.180	1.190	1.10	0.85	0.48	0.35	0.21
Movement from 40 to 0°C	0.471	1.98	2.65	3.276	3.68	3.58	2.50	1.75	1.02	0.45
Clyde silt loam:										
Beginning of experiment	7.56	12.51	14.98	17.59	18.80	21.55	22.76	29.98	34.57	....
Movement from 20 to 0°C	0.122	0.46	0.89	0.96	1.07	0.99	0.83	0.62	0.29	....
Movement from 40 to 0°C	0.409	1.72	2.07	2.45	3.27	2.82	2.30	1.36	0.51	....
Clay:										
Beginning of experiment	9.70	18.38	19.29	20.69	22.98	29.88	....	....	....	....
Movement from 20 to 0°C	0.248	0.72	0.99	0.73	0.70	0.681	....	....	....	....
Movement from 40 to 0°C	0.672	2.60	3.29	2.50	2.12	1.88	....	....	....	....

a sieve and then mixed thoroughly. It was then placed in the tubes and packed uniformly by allowing the tubes to fall in a vertical position from a certain height a definite number of times.

At the end of each experiment the warm column was separated from the cold column of soil by means of a spatula. This was done by drawing out all the soil from that warm section of the tube which extended up to the plane of the partition and allowing for the cold column of soil all the soil that was contained in that cold section of the tube up to the other plane of the partition, and also that portion of the soil contained in the tube under the hole of the partition. This last part of the soil was accorded to the cold column of soil because its temperature is intermediate between the opposite temperature extremes and it was desired to make the lines of demarcation between the two columns of soil as prominent and distinct as possible. The moist soils were dried in an electrical oven for about 20 hours at a temperature of 105° C., and the percentage of moisture content was calculated on the dry basis. The weights were always made on a sensitive chemical balance.

The fact has been mentioned that the mobility of moisture from warm to cold column of soil was studied in two different ways: (1) when the column of soil stood horizontally, and (2) when it stood vertically. The data obtained from both series of experiments show that if the same percentages of moisture were employed practically the same results were obtained, no matter whether the soil columns remained in the horizontal or vertical position. For sake of brevity and simplicity of presentation, therefore, only the results of the series of experiments wherein the soil column was held in the vertical position, will be presented here. These experimental data together with their diagramatic representations are submitted below. Table 2 contains the different soils with their various moisture contents, and the percentage of moisture moved from the column of soil at 20° to the column of soil at 0° C., and from the column of soil at 40° to the column of soil at 0° C. The percentage of moisture moved represents the difference between the percentages of moisture found in the cold and warm columns of soil respectively at the end of the experiment; at the beginning of the experiment the moisture content was the same in both columns of soil. Figure 2 represents all these data in a graphical form.

The foregoing data present many important and remarkable facts. First of all, they show most emphatically that the *a priori* prediction regarding the thermal movement of moisture as deduced from the laws of surface tension and viscosity in their relation to temperature, is not strictly realized. According to these laws the amount of water moved from warm to cold column of soil should be the same for all moisture contents, providing the soil mass exerts no influence upon water; inasmuch, however, as the soil does exert an adhesive force for water, then the thermal translocation of moisture should increase with rise in water content. *Instead, the percentage of water moved from warm to cold column of soil, at both temperature amplitudes, increases regularly and rapidly with increase in moisture content in all the different types of soil, until a certain moisture content is reached and then it commences to decrease with further rise in percentage of water. The results plot then into a parabola, with a maximum point, instead of a straight line.* This maximum point of water thermal translocation is significant in at least two ways: (1) it is quantitatively about the same for all diverse classes of soil, and qualitatively the same for both amplitudes of temperature, and (2) it is attained at entirely different moisture contents in the various soils, and at a comparatively low percentage of moisture. On referring to the data in table 2 it will be seen that the maximum thermal

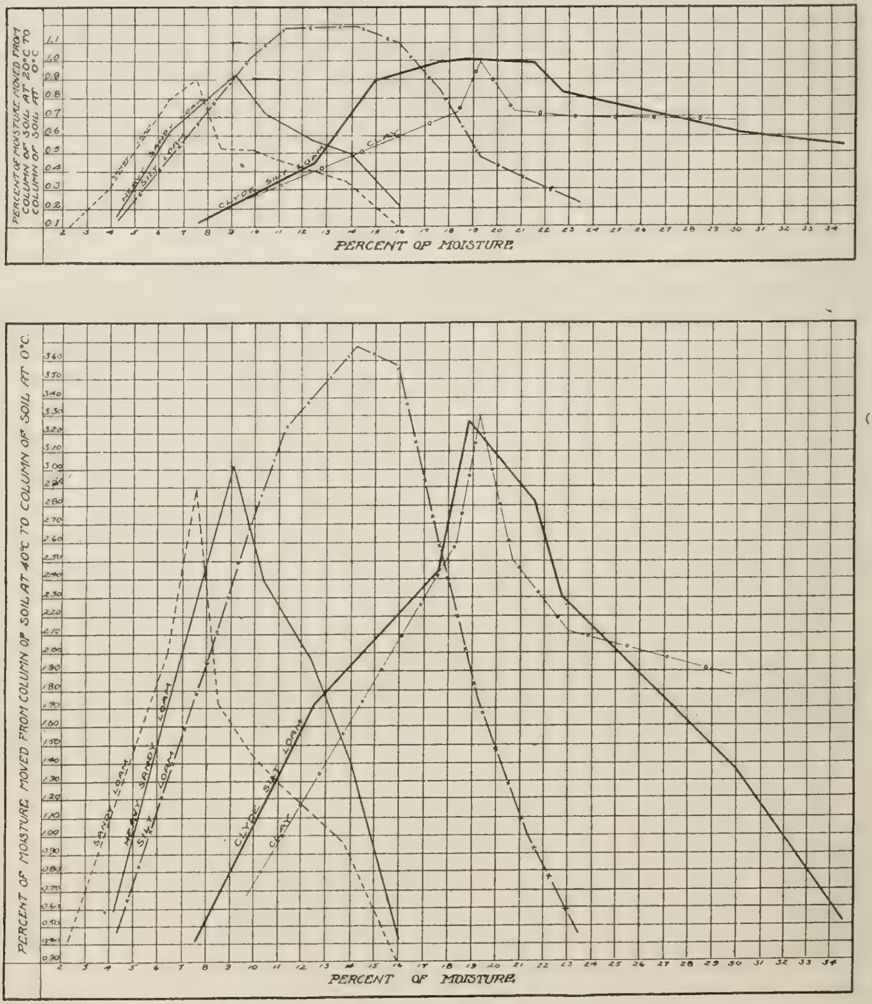

FIG. 2. CURVES SHOWING MOVEMENT OF MOISTURE FROM WARM TO COLD COLUMN OF SOIL OF UNIFORM MOISTURE CONTENT.

water transference at the amplitude of 20° C. is 0.90 per cent for light sandy loam, 0.93 for heavy sandy loam, 1.19 for silt loam, 1.07 for Clyde silt loam, and 0.99 for clay; at the temperature amplitude of 40° C., it is 2.88 per cent for light sandy loam, 3.02 for heavy sandy loam, 3.68 for silt loam, 3.27 for Clyde silt loam, and 3.29 for clay. It should be noted that the percentage of thermal motion of water increases more than proportionally with temperature. The temperature of 40° C. for instance, is only twice as great as 20° C. while the percentage of moisture moved is three times greater in the former case than in the latter. The water content of the various soils at which the maximum thermal translocation occurs is 7.50 per cent for light sandy loam, 9.08 for heavy sandy loam, 14.21 for silt loam, 18.80 for Clyde silt loam, and 19.29 for clay.

Obviously then, the maximum thermal water movement depends upon a definite condition of moisture of any particular soil; a deviation from this definite degree of moisture in either direction causes a decrease in thermal movement of water. Since this definite percentage of moisture at which the greatest quantity of water is able to move from warm to cold column of soil appears to be a specific constant or characteristic of the various soils, it is proposed to designate it as *thermal critical moisture content.* A thermal critical moisture content may be defined then as that percentage of moisture in a soil which allows the greatest amount of water to move from a warm to a cold soil at any amplitude of temperature.

A further examination of the preceding experimental data shows that the thermal movement of moisture is extremely sensitive to the amount of water present in a soil. It will be noted that by increasing or decreasing the percentage of soil water by small degrees the thermal movement varies very markedly in either direction. From this it follows that the thermal critical moisture content must be quite definite, and in order to obtain it absolutely the percentage of soil moisture near the point of maximum thermal movement must be increased by small amounts. This applies especially to the light sandy soil in which the sensitiveness appears to be more marked and the range more limited. If the increase in percentage of moisture content took place in this soil by 0.1% instead of 1.0% the maximum thermal translocation would probably have been as high as that of the other soils. It is possible, however, that the value obtained is about the upper limit for this soil and consequently for all soils of its type.

The diminution of the thermal translocation of water with decrease in moisture content from the point of thermal critical moisture content, might be anticipated, but the decrease of water movement with further increase of moisture content after the point of thermal critical moisture content, was not expected. Indeed, it was at first thought that the movement would be greater at the highest moisture contents because there would also occur a gravitational movement. When soils containing as high as 35.0 and 30.0 per cent of moisture as did the Clyde silt loam and the clay respectively and when one-half of their column is kept at 40° C. and the other at 0° C. for 8 hours, such expectation as the above is not at all unnatural. Instead, the water movement at these highest moisture contents is very low, and in descending order, and the cessation of diminution is not as yet reached. These results go to show then, in a most striking manner, that the soils possess a very great attraction for water, and that their requirements for water to satisfy their attractive forces before free movement of water can take place, are indeed high. Until the point is reached where gravitational movement occurs the moisture in the soil is held by a force of great magnitude.

Now, the next question is how may this peculiar thermal translocation of water be explained? What are the causal agents which bring it about?

As already stated it is not entirely due to the surface tension and viscosity of the soil water; for if that were the case then the movement should have followed a different course. If the soil exerted no adhesive force for water than the amount of moisture moved from warm to cold column of soil should be the same for all moisture contents, providing the force of gravity is eliminated, for any particular amplitude of temperature. But since the soil does exert a strong adhesive force for water then the thermal motion of water should follow a straight line with rise in moisture content, for any given difference in temperature. Instead, the results plot into a parabola. Evidently, there must be another explanation for the phenomena.

The best explanation that is suggested appears to be founded upon the following four assumptions: (1) The soil possesses an attractive power for water and holds it with a great adhesive force; (2) these attractive and adhesive forces decrease with increase in temperature; (3) the surface tension or cohesive power of the liquid also diminishes with rise in temperature; and (4), the force due to the curvature of the water films between the soil grains which are known as capillary films, decreases with increase of water content.

All these four assumptions appear to be correct. The validity of the third and fourth is generally recognized and consequently need no further discussion. The validity of the first is also universally accepted; that the soil possesses an attractive power for water can hardly be denied; that the soil holds the water with a great adhesive force is evidenced by the great difficulty experienced in attempting to separate the one from the other. Indeed, this adhesive force is so great that no method as yet has been devised either to execute a complete separation of the two components, or to measure with any degree of precision its magnitude. The researches of Lagergren[1], Young[2], and Lord Rayleigh[3] indicate, however, that this force may be an order of magnitude from 6,000 to 25,000 atmospheres. As the water content increases this force decreases.

The great attractive and adhesive forces which the soil exerts for water are further illustrated by the researches of Briggs and McLane on the moisture equivalent and those of Briggs and Shantz[4] on the wilting coefficient of plants[5]. By whirling wetted soils in a rapidly revolving centrifuge, fitted with a filtering device in the periphery, and developing a force equivalent on the average to 3,000 times the attraction of gravity, Briggs and McLane found that some clay soils would still contain about 50% of water. Biggs's and Shantz's studies on the wilting cœfficient of plants show that plants would wilt and die in clay soils even when the moisture content was still about 30%.

Of all the four assumptions the correctness of the third, namely, that the attractive and adhesive forces decrease with rise in temperature may be doubted by many and challenged by few; the theoretical and experimental evidences, however, are overwhelmingly in its favor. According to the law of kinetic energy the attractive and adhesive forces of solids for liquids, and gases or vapors, should decrease with rise in temperature. The investigations upon the absorption of gases and vapors at different temperatures show such to be the case. The work of de Sausure[6] and Von Dobeneck[7] upon the absorption of gas by different solid materials, and the researches of Knop[8] and Ammon[9] upon the absorption of water vapor by soil, seem to show conclusively that the absorptive power of diverse solid materials for gases and water vapor, decreases with increase in temperature. The only evidence which is contrary to the above is that obtained by Hilgard[10] on the absorption of water by dry soils from a saturated atmosphere. Hilgard's results show that the absorption of water vapor by soils increases with rise in temperature. The results obtained by the several investigators mentioned as well as new evidence which will subsequently be presented, tend to throw considerable doubt on the correctness of Hilgard's data. Hence, it can safely be asserted that the third assumption is correct.

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[1] Uber die beim Benetzen fein verteilter Körper auftretende Wärmetönung von Lagergren, Behang till K. SV. Ve-takakt., Handl.. 24, afd, 11, No. 5, 1898.

[2] Hydrostatics and elementary hydrokinetics, G. M. Minchin, p. 311, 1892.

[3] On the theory of surface forces, by Lord Rayleigh, Phil. Mag. (5), 30, 285-298, 456-475, (1890).

[4] Bulletin 45, U. S. Bureau of Soils.

[5] Bulletin 230, U. S. Bureau of Plant Industry.

Bearing these postulates in mind the phenomena of thermal water translocation observed may be explained as follows: The soil with lowest moisture content holds the water with a force of great magnitude. When the temperature of a column of this soil is uniform throughout the adhesive and attractive forces are at an equilibrium. When one half of this column of soil is heated to 40° C. and the other half to 0° C. this equilibrium is disturbed. The attractive and adhesive forces of the soil for water and the cohesive power or surface tension of the soil water are decreased in that portion of the soil column which is maintained at 40° C. and increased to a corresponding magnitude in that portion of the soil column which is kept at 0° C. The cold column, therefore, exerts a pull and draws water from the warm column in amount depending upon the quantity that the warm column of soil is willing to give up. Since the soil possesses a great attraction for water, which attraction varies with the diverse classes of soil, and inasmuch as this attractive force is not satisfied at the low moisture content, the warm soil parts only with a small amount of its water. Hence, the amount of water moved from the warm column to the cold column of soil, is small. At the next higher moisture content the attractive power of the soil for water is further satisfied and the total water content is held with less force. When a column of this soil is kept at the same amplitudes of temperature as above, the decrease and increase of the adhesive and cohesive forces, due entirely to temperature, between the warm and cold columns of soil are equal in amount as in the soil with the lowest moisture content. Water, therefore, tends to move from the warm to the cold soil. Inasmuch, as the attraction of the soil has been further satisfied and the water films further thickened, the pull of the cold soil, due only to the attractive forces of the soil for water, is decreased, but the ease with which the warm soil gives up moisture is, on the other hand, increased. The result is that even though the total effective pull (which is composed of the increased surface tension of water, increased attractive and adhesive forces of soil for water, and the force of the curvature of the capillary films) of the cold soil with the high moisture content is less than that of the soil with low moisture content, the greater ease with which the warm soil with high water content parts with moisture enables the reduced affective pull to draw more water from the warm to the cold side. As the moisture content of the soil is continually increased its attractive power is satisfied and the curvature of the capillary films decreased, correspondingly; the total effective pull of the cold column of soil is continually decreased but the ease with which the warm column of soil gives up moisture is also continually increased, so that the thermal translocation of water is constantly increased with rise in moisture content. Finally, a degree of moisture content is reached in which the effective pull of the cold column of soil is able to extract the greatest amount of water from the warm column of soil. This degree of water content is the *thermal critical moisture content.* At this point the attractive power of the soil for water is considerably satisfied but far from being entirely appeased; the total effective pull of the cold column of soil is also considerably less than that of the preceding columns of soil, but the warm column yields water to this pull with such ease that there occurs a maximum thermal water translocation. Inasmuch as the water attractive power is different for the various kinds of soils, this thermal critical moisture content is necessarily different. After this thermal critical moisture content is reached the effective pull of the cold column of soil is further decreased with continued increase of moisture content; and although the willingness of the warm column of soil to part more readily with moisture is also increased, yet the pull of the cold column of soil is not sufficiently strong to draw it, and consequently the thermal movement of water commences to decrease; and continues to diminish very regularly and gradually with continued increase in moisture content. When the highest percentage of water is reached the warm soil is very willing to part with a very large amount of water but since the effective pull of the cold soil is reduced almost to minimum, only a small amount of moisture is drawn from the former to the latter.

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[6] Ann. Phys. Gilbert, 47, 113 (1814).
[7] Forsch. Agr. Phys., 15, 163 (1892).
[8] Cited by Johnson, How Crops Feed, pp. 161-162, (1870).
[9] Forsch, Agr. Phys., 2, 163 (1892).
[10] Soils, p. 198 (1912).

The degree of moisture of the different soils could not be further increased on account of the difficulty of sifting them, and consequently it cannot be stated with certainty whether the thermal movement of water would become zero at a still higher moisture content. From the theoretical point of view, however, it should not become zero because the pull due to the surface tension of water alone is not affected by increase of moisture content, but remains constant. The portion of pulling force which is decreased constantly with rise in moisture content is that pertaining to the attractive power of soil for water, and to the curvature of the capillary film. At or near the point of saturation the pulling power due to these two factors is probably zero; at this point the soil may be considered to be passive. Any thermal movement of water that takes place at or near the point of saturation is to be attributed to the surface tension of the soil water. If this assumption is correct, and if the percentage of moisture moved at the highest moisture contents employed, is to be considered as a measure of the amount of thermal translocation due to surface tension of water alone, it will be found that the quantity due to this force, is very small indeed. As will be seen from the experimental data, the percentage of moisture moved at both amplitudes of temperature is reduced to an insignificant value at the highest moisture contents.

The foregoing exposition as to the cause and mechanism of the phenomena of thermal water translocation, will probably be made more clear by figure 3. This diagramatic representation, however, by no means pictures the real cause and mechanism, absolutely and accurately, but it will serve, it is believed, to make what has already been said more clear.

Let the ordinate represent the effective pull of the cold column of soil, and the willingness of the warm column of soil to part with water, at

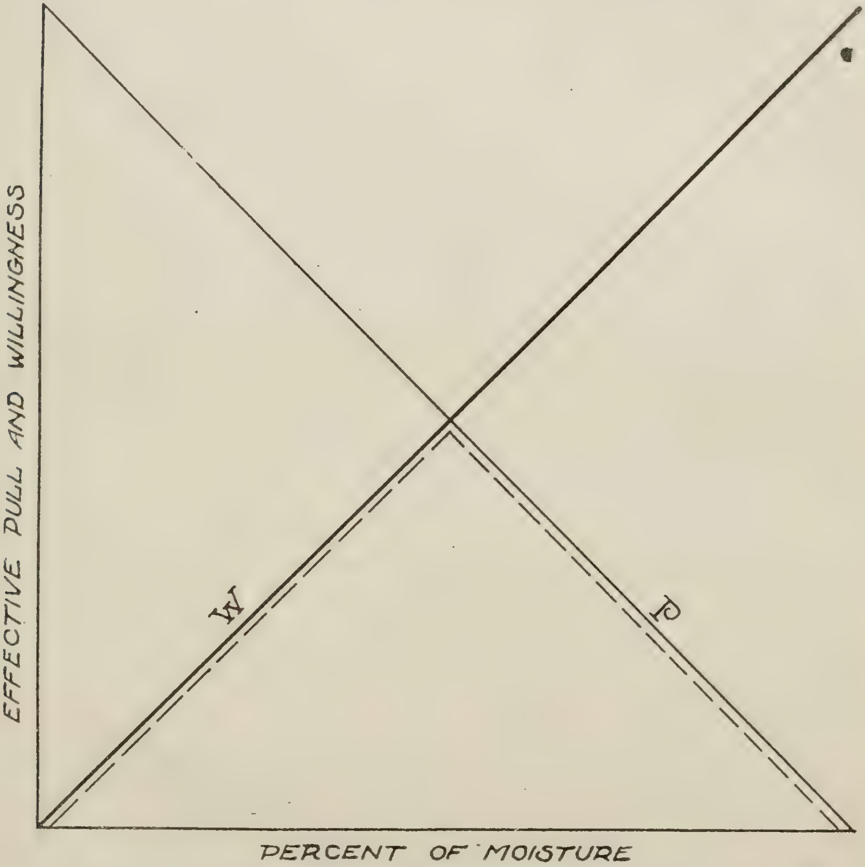

FIG. 3. CURVE ILLUSTRATING THE CAUSE AND MECHANISM OF THE THERMAL MOVEMENT OF WATER IN SOILS OF UNIFORM MOISTURE CONTENT.

different moisture content; and the abscissa, the different percentages of water contained by the soil. By plotting the effective pull and willingness against the moisture content it will be seen that the effective pull decreases and the willingness increases, with rise in moisture content. At the point where the two lines cross probably occurs the maximum thermal translocation of water. After this point of intersection, the willingness of the warm soil to give up water is large, but since the effective pull is being reduced to minimum, the water is not moved. If now a parabola is drawn along the lines WP with its maximum value at the point of intersection, then this theoretical curve agrees almost perfectly with the real one in figure 2.

The serious fault with the above illustration is that the total effective pull tends to become zero, and, theoretically, this should not be the case, because while the pull due to the attractive power of the soil for water, and to the curvature of the capillary films will ultimately become zero, the pull due to the increased surface tension of the soil water should not become zero, but should remain the same for all moisture contents. Hence, the above diagram illustrates more correctly only the thermal translocation of the water as due to all the other forces except to the surface tension of water.

The next important question to consider is the mode and amount of thermal translocation of water in field soils as suggested by the foregoing laboratory experimental data. Under field conditions the soil moisture exists practically always in a gradient form. As the water content tends to decrease upwards from the water level, the forces due to the curvature of the capillary films, and to the attractive power of the soil for water, increase correspondingly, consequently the pull is upward. The soil temperature also exists in a gradient form, but this reverses itself diurnally and therefore modifies these pulling forces. During the day the temperature at the upper depths is higher than that below, the attractive and adhesive forces of the soil for water, and the surface tension of water, are decreased, so that the total upward effective pull is diminished correspondingly. Inasmuch as the temperature below is less than that above, the effective pull due only to the increased attractive and adhesive forces of the soil for water and to the surface tension of the soil water, should occasion a downward movement of moisture. Since, however, the water attractive forces of the soil below are more satisfied than those of the soil above, the downward pull, due only to the attraction, adhesion and surface tension as increased by a lower temperature, is very small in comparison with the upward pull. Hence, during the day, the moisture movement is upward. During the night, nearly all of the above forces act in a parallel direction and favor an upward movement. *Hence, the thermal movement of capillary moisture in soils is always upward and never downward.*

The extent to which moisture will move during the night from the warmer soil below to the colder soil above will depend, (1) upon the soil temperature gradient, that is, upon the difference in temperature of the various adjacent depths, and (2) upon the gradient or amount of moisture content at the various depths. In the preceding series of experiments the temperature amplitudes of 20° and 40° C. were employed. In nature, however, so large and sharp variations in temperature between adjacent depths never occur during the night; (they do occur, however, at the upper depths between day and night). Soil temperature investigations which are being conducted at this Station show that in the early morning when the temperature gradient is most marked, the temperature of the bare mineral soils increases, sometimes in the summer and fall at the average rate of about 2° or 3° C. for each inch depth down to about 4 inches and then this rate becomes less. In cropped soils, where the temperature remains more constant, this rate of increase of temperature with depth is still less. *Hence, the amount of thermal translocation of water that would occur during a single night would be very small.* On the other hand, the maximum thermal translocation of water obtained in the preceding series of experiments was procured from column of soil with uniform moisture content. As will be shown subsequently there is no doubt whatever, but that this maximum thermal translocation of water in the various soils would have been far greater if the moisture content of the cold column of soil was less than that of the warm column of soil. In nature, as already mentioned, the moisture exists in a gradient form and consequently the movement of water is upward, and the forces of the factors which cause this upward movement are increased during the night. *Hence, while the amount of thermal translocation of water during a single night in bare soils under field conditions may not be as great as that obtained in the foregoing series of experiments, yet it will be quite appreciable; and since the process is repeated, the sum of water translocation of all the nights during the vegetative season, will probably be considerable.*

The moisture content at which the maximum thermal translocation of water occurs, or what has been designated as the thermal critical moisture content, is very significant and needs further consideration. It would be of very great interest to know, for instance, what the thickness of the water film around the particles is at this degree of moisture. This thickness could be calculated if all the soil grains were solid and spherical. The particles of the soils used, however,—and these are the commoner types of agricultural soils—are neither spherical nor solid. Nearly all the particles in agricultural soils can be said to be irregular in shape; some of them are solid and enveloped with a colloidal coating; others are compound aggregates or "crumbs" and are porous; and still others, mainly of the peat nature, are of a sponge structure, and are necessarily porous. The particles of a soil or soils may be classified under two categories: (1) particles which are solid and have only an external surface, and (2) particles which are partly or wholly porous and possess both an external and internal surface. In the case of the solid and cleaned surface particles, the water film is spread over the surface, but in the case of the solid particles coated with colloids, or the mineral flocules and the organic particles, the film of water envelopes, theoretically, their whole external surface, and also water permeates their internal surface. The single solid mineral grains, which may compose the compound particles, may be cemented together in a way analogous to that found in a piece of sandstone, in which case the water exists only in the interstices and not as a complete film around each particle. Furthermore, whether the soil grains are solid or spherical, or compound and porous, the water film is not uniform in thickness over the entire inner surface of the soil mass, but thickens more at the capillary angles between the particles.

In view of these considerations, therefore, it was considered useless to attempt to compute the thickness of the film as many investigators have done. *Furthermore, in view of the nature of the soil particles as discussed above, it does not appear strictly proper to define the capillary water in the soil as many writers do as a thin film overspreading the particles and thickened into a waist-like form at their points of contact.* Hence, a new definition of capillary water is needed.

If we are to accept the theory which has been used to explain the foregoing phenomena of thermal translocation of water that the soil possesses a very great attraction for water, that this attractive force is different for various soils, that it decreases with a rise in moisture content, and that it is completely satisfied at a rather high moisture content, then our present views concerning the movement of capillary water in *moist soils* needs modification. The present theory regarding the capillary movement of water consists of an analogy from the rise of water in capillary tubes. The interstitial spaces of a soil mass are considered as forming channels analogous to capillary tubes, and are often designated as bundles of capillary tubes. The capillary water is believed to exist as surface films around the particles, and as capillary films in the capillary spaces between the particles, and its movement is said to depend entirely upon the curvature of the capillary films. When a dry soil, for instance, is well moistened and brought to equilibrium, the water films are thick and the curvature of the capillary films small, and there will be no further capillary attraction of water if this soil is brought in contact with water. If now this soil is allowed to dry at the top the surface films become thinner and the force of the capillary films increases in direct ratio with their degree of curvature, hence, there will be a pull of water from the thicker surface films and less curved capillary films below, towards the surface.

It is obvious that this theory of capillary movement of water attributes the whole cause of the capillary motion of water in a moist soil to the curvature of the capillary films between the particles, and considers the moist soils as being passive, inactive, and exerting no influence whatever upon the motion of water. Indeed, Briggs[11] and Lapham in trying to explain the differences in capillary action in dry and moist soils, make the following statement: "In a moist soil, however, we have quite another condition. A film of the liquid covers all the surfaces of the soil grains. Since this film, once established, is maintained in a saturated atmosphere, it follows that the soil-air and solid-liquid surfaces forces no longer play any part in the capillary movement, which is produced entirely by the air-liquid surface force and is opposed only by the weight of the liquid column." In view of this general belief Briggs, as well as other investigators, has tried to alter the properties of the soil water, by increasing its surface tension, etc., with the object in view of increasing its capillary action.

If it were true that as long as a thin film of water is maintained in a damp or slightly moist soil, the soil material itself exerts no longer any influence upon the movement of capillary water, then the preceding theory might be true. But we have seen in postulate (1) page 14, that the soils and especially those rich in colloidal material, possess a very great attractive power for water, that this attractive power is satisfied only at a rather high moisture content, that as long as it is not satisfied the soils will continue to take up water, and that they hold the water with a force of great magnitude. *In view of the considerations presented in this postulate and in view of the fact that the preceding thermal movement of water appears to be largely controlled by the attractive forces of the soil for water, it seems wrong to consider the soil material in moist condition as a static, passive, inactive and irresponsive skeleton upon which the liquid plays its role. The soil material, in moist condition, short of saturation, is dynamic and not static in respect to moisture movement. Hence, the capillary movement of water should*

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[11] U. S. Dept. of Agr. Bureau of Soils Bulletin No. 19, p. 28 (1902).

not be attributed entirely to the forces exerted by the curvature of the capillary films, but also to the forces exerted by the unsatisfied attractive power of the soil for water. When a moist soil, therefore, begins to lose water at the surface two effects are produced: (1) the attractive forces of the soil for water are increased, and (2) the curvature of the capillary films is increased, both of these effects exert a pull on the moist soil below and tend to draw water to the surface. As to which one of these two forces exerts the greatest pull, it is impossible to say, because there is no way of measuring them. It is certain, however, that the force resulting from the attractive power of the soil for water must be very considerable, and probably it is the predominant of the two.

It might be argued that the preceding phenomena of thermal translocation of water could be explained entirely by the film theory, without having to resort to the conception of the attractive forces of the soil. Such a contention, however, cannot be maintained, first because it cannot be conceived that the tension of the capillary films is operative and effective at such high moisture contents employed, and secondly, because the fact remains nevertheless that the soil exerts a pull due to its attractive forces for water as has been abundantly proved. Furthermore, if it is maintained that the attractive forces of the soil for water are satisfied as soon as the soil is merely dampened, then why should the soil hold additional large amounts of water with such a great force that it is impossible to extract it with mechanical means? It seems reasonable, therefore, to believe that if the soil holds large amounts of water with a great force, it should attract or absorb it with a force of equal magnitude.

MOVEMENT OF MOISTURE FROM MOIST AND WARM COLUMN TO DRY AND COLD COLUMN OF SOIL WITH AN AIR SPACE BETWEEN THE TWO COLUMNS.

In the preceding section the thermal translocation of water was considered as occuring as water film phenomena. There is still another way in which this thermal mobility of moisture might take place, this is by evaporization and condensation of soil water from a point of high temperature to a point of low temperature. It is well known that water undergoes a transformation into the vapor state by the application of heat, and the quantity of liquid vaporized increases with rise in temperature. One of the remarkable characteristics of aqueous vapor is its sensitiveness to heat, changing from gaseous to liquid state and vice versa with very small variations in temperature. As an excellent paradigm of this latter fact may be cited the relative humidity of the air at different temperatures.

Since the temperature gradient of the soil reverses itself during the night, that is, it increases with depth, it is believed that there is a rising of vapor or moist air from the warmer soil below to the colder soil above where the moisture is condensed. As a manifest proof of this theory the morning dew is cited. It is concluded, therefore, that a large part of the water movement in soils is due to this process, There appear to exist no direct experimental data as to whether or not there really is a translocation of moisture in soil at night, due to upward movement of the moist warm air, and the condensation of its moisture at the cold soil above. Practically all our present knowledge upon the subject consists of theoretical deductions and from practical observations.

With the object of obtaining experimental evidence upon the subject the following investigation was performed: Into brass tubes 8 inches long and 1½ inches in diameter was placed moist soil at one end and dry soil at the other, and the two columns separated by an air space. This air space was ¼ inch in height and 1½ inches in diameter and was produced by placing between the two columns of soil a ring of cork the two sides of which were closed with wire gauze which acted as supports of the two soils and prevented their particles from coming in contact. The tubes were then placed horizontally in the boxes shown in figure 1. That part of the tubes which contained the moist soil was kept at 20° and 40° C., and the part which contained the dry soil was maintained at 0° C. The experiment was allowed to run about 8 hours. If during this period the dry and cold soil gained any moisture it obtained it by the condensation of vapor which was produced at the warm and moist soil. Since the dry soil possesses a high absorbtive power for water it was assumed that it abstracted the vapor from the air space and that this air space was thus prevented from attaining an equilibrium. There were five different classes of soils used, quartz sand, Miami light sandy loam, Miami silt loam, Clyde silt loam, and Miami clay. The moisture contents employed for each soil were three low, medium, and high. The results obtained are presented in table 3. The percentage of moisture moved from the warm and moist column of soil to the cold and dry column of soil represents the difference between the percentages of moisture found in the dry soil at the beginning and end of the experiment.

TABLE 3.—PERCENTAGE OF MOISTURE MOVED FROM WARM AND MOIST COLUMN OF SOIL TO COLD AND DRY COLUMN OF SOIL WITH AN AIR SPACE BETWEEN THE TWO COLUMNS.

Kind and temperature of soil.	Percentage of moisture.		
Quartz sand:			
Moisture in moist column	2.90	6.83	13.52
Movement from moist column at 20°C., to dry column at 0°C	0.051	0.046	0.048
Movement from moist column at 40°C., to dry column at 0°C	0.286	0.280	0.294
Sandy loam:			
Moisture in moist column	7.23	10.27	15.82
Movement from moist column at 20°C., to dry column at 0°C	0.0238	0.0313	0.0246
Movement from moist column at 40°C., to dry column at 0°C	0.211	0.253	0.223
Silt loam:			
Moisture in moist column	9.16	14.52	16.40
Movement from moist column at 20°C., to dry column at 0°C	0.024	0.033	0.0273
Movement from moist column at 40°C., to dry column at 0°C	0.278	0.273	0.288
Clyde silt loam:			
Moisture in moist column	9.85	15.51	23.39
Movement from moist column at 20°C., to dry column at 0°C	0.028	0.031	0.040
Movement from moist column at 40°C., to dry column at 0°C	0.16	0.22	0.28
Clay:			
Moisture in moist column	10.77	15.36	20.35
Movement from moist column at 20°C., to dry column at 0°C	0.08	0.06	0.09
Movement from moist column at 40°C., to dry column at 0°C	0.18	0.36	0.26

The above results show the most surprising fact that the amount of moisture moved from the moist and warm column of soil to the dry and cold column of soil by vapor is very insignificant indeed. It will be seen that at the temperature amplitude of 40° C. the quantity of moisture moved is only about 0.25%, and at the amplitude of 20° C. the value is only about 0.035%. In comparison with the results of table 2 where it is shown that the maximum thermal movement of water at the thermal critical moisture content, when the soil mass is continuous, runs as high as 3.68% in some cases, then the above values, due only to vapor movement and condensation, are extremely insignificant.

From these results then it is safe to conclude that the thermal movement of moisture due to distillation is practically negligible, even at such high amplitudes of temperature of 20° and 40° C. which never exist during the night at the different adjacent depths in the soil, nor during such a long continuous period as 8 hours. This conclusion is indirectly substantiated by the studies of Buckingham[12] on the loss of soil moisture by direct evaporation from points below the surface. By exposing a surface of water or moist soil to evaporation into a confined space which was in communication with the outside air through a column of soil, Buckingham found that the actual mean rate of loss of water through diffusion of water vapor through soils in still air, was very small.

Another noteworthy fact to be noticed in the foregoing experimental data is that the amount of distillation from moist and warm to the dry and cold column of soil is the same for all moisture contents. This might have been anticipated since the amount of water vaporized depends principally upon the temperature and is not governed by the amount of water present. On the other hand, if the amount of water present in the soil is extremely small, the water is held by the soil grains with an attraction of great magnitude, causing a lowering of the vapor pressure of the absorbed water film and thereby producing a diminution in the rate of evaporation. Perhaps the water contained in the soil with the lowest moisture content was above the point where this lowering of vapor pressure occurs, and consequently the partial pressure of the vapor in the air space in this soil was the same as in the air space of the soil with the greater moisture contents. Furthermore, the values are so small as to be within the experimental error, and the method of moisture determination may not be sufficiently sensitive and accurate to show any decreased evaporation by the soils with the lowest moisture content.

In undertaking and performing the foregoing series of experiments it was taken for granted that there really is an upward movement of moist air during the night from the warmer soil below to the colder soil at the surface, where its vapor is condensed. This theory seems to be now very widely accepted as already stated. The formation of the dew is attributed by many writers almost entirely to this thermal movement of vapor. Thus, in discussing the subject Hilgard[13] states ...... "dew is formed from vapor rising from the warmer soil into a colder atmosphere, and condensed on the most strongly heat-radiating surfaces near the ground, such as grass, leaves both green and dry, wood and other objects first encountering the rising vapor." Farther on he says: "The fact that dew is most commonly derived from the soil could have been foreseen from the other fact, long ascertained and known, that during the night the soil is as a rule warmer than the air above." Other writers, such as Ramann[14], etc., claim in substance the identical belief.

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[12] U. S. Dept. of Agr., Bureau of Soils Bulletin No. 38 (1907).
[13] Soils, p. 307 (1912).

But really, is there a rising of vapor or warm moist air from the warm soil below to the cold soil above? And is the source of water of the dew due to this soil vapor? During the day the soil receives its heat at the upper surface and its temperature rises. The heat is conducted downward and the temperature of the various depths of the soil increases correspondingly. The temperature at the surface continues to rise until a maximum is reached and then commences to decrease. As the temperature rises and moves downward the soil air expands, and as the volume of the pore space remains constant, it is expelled into the atmosphere. The pressure of the soil air at the different depths tends to be the same at any one time and equal to the atmospheric pressure, provided the communications are ideal. When the temperature at the surface soil is at maximum it is generally many degrees higher than that of the air above, amounting sometimes to 30° C. In fact the air temperature decreases, in calm and clear weather, with increase in height at the adiabatic rate of approximately 0.9° C. per 300 feet. When the temperature of the surface soil and of the air is highest the atmospheric pressure also tends to be at its minimum, so that the air escapes from the soil with greater facility. After the surface soil attains its maximum temperature and then begins to cool, its air contracts, tends to produce a partial vacuum, and consequently draws air from the atmosphere, so its pressure will be in equilibrium with that of the latter. The fall of temperature is also conducted downward, and proceeds as a wave, and as it descends it causes a diminution in volume at the corresponding depths, and therefore produces an inward flow of air. This cold wave, however, is preceded by the maximum temperature wave which, as it proceeds downward, causes a further expansion of air, which goes to make up for the decreased volume of air caused by the cold wave following immediately after. The difference in temperature, however, of the soil at any depth immediately before and after the maximum temperature wave is reached is very small, as experiments at this Station show, and consequently the expansion and expulsion of air caused by the downward march of the maximum temperature wave is not very appreciable. Hence, as the cold wave proceeds downward and produces a decrease in volume of the soil air, the air that comes to make up for this decrease, so that an equilibrium of pressure will exist, is mainly from the outside atmosphere. After a certain depth is reached the maximum temperature wave entirely disappears, and there is no more upward expulsion or movement of air. From now on, as the temperature of the soil is further decreased and the volume of its air is diminished correspondingly, the current of flow of air into the soil is entirely from the outside atmosphere. This downward flow of air will continue until the soil temperature begins to rise again and the cycle recommences. When the minimum temperature of the surface soil is reached, it is as a rule, about the same or slightly higher, than that of the air immediately above. The temperature of the air at about this period increases with the height, in the same manner as the temperature of the soil increases with depth, which is just the opposite from what it is during the day. This increase instead of decrease of a temperature at night with rise in elevation is called surface temperature inversion. At this minimum temperature the atmospheric pressure approaches its maximum, and the inward flow of air is thereby facilitated.

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[14] Bodenkunde, p. 382 (1911).

All the foregoing facts lead to the enunciation of a general law that during the day, as the temperature rises, the soil air tends to flow outward into the atmosphere, and during the night, as the temperature falls, air from the atmosphere tends to flow inward into the soil. This law diametrically opposes the prevalent theory that during the night there is an upward movement of moist warm air. The above law, however, seems to be borne out by logic and appears to be confirmed by experimental evidence subsequently to be presented. The prevalent theory, however, seems unreasonable. For instance, if it is admitted, which it must be, that the soil air escapes into the atmosphere during the day as the temperature rises, then where and when does the soil obtain its air if it continues to give up air even during the night? It might be argued that it is vapor that is rising to the surface and not air. That is inconceivable in the present case. It is true that distillation would occur if the amplitude of temperature were appreciable and constant, but it has been shown that the temperature of the whole column of soil decreases constantly, and that an air current from the cold atmosphere is drawn inward which tends to encounter and oppose any upward movement of vapor rising from any difference in temperature. Moreover, granting for sake of argument that there is a vapor rising from the warmer soil to the colder soil at the surface, the amount would be extremely small to account for the great quantity of dew commonly noted, because the temperature amplitudes of the soil at different depths at night are never very great. In fact, during the spring months as the temperature of the lower depths continually rises and the trend of the air temperature is upward, the range of temperature between the surface and the lower depths say 4 inches, is small, usually amounting only to about 2 or 3° C. The greatest differences in temperature at the different depths in the morning occur in the fall when the trend of the air temperature is downward and the surface soil temperature continually falls. At this time the variation in temperature between the surface and six inches of the mineral soils may be as high as 8° C. but the variation between adjacent depths is only from about 0.5° to 2° C.

The truth of the matter, however, seems to be that instead of vapor rising from the warmer soil below to the colder soil at the surface, vapor enters the soil from the atmosphere. This is a natural conclusion from the law enunciated that during the day air is exhaled from the soil and during the night air is inhaled from the atmosphere. The amount of moisture that will thus enter the soil will depend upon the quantity of air inhaled and upon its absolute humidity, but as will be seen subsequently it is extremely small. The water may be abstracted by the dry soil at the surface as the air is drawn in or it may enter unaffected. Thus, it is possible that the moisture lost by the soil during the day *by the expulsion of its moist air* is partly, if not wholly, regained at night.

What is then the source of water of the dew? The greatest part of it comes from the lower layer of the atmosphere itself by condensation. Some of it comes from the leaves of trees and plants. And a certain amount comes from the soil by capillary and thermal capillary action as set forth previously.

According to the foregoing consideration, therefore, the notion that "dew is formed from the vapor rising from the warmer soil into a colder atmosphere" is wrong, and those who proposed and adhere to this theory seem to be laboring under misapprehension of facts.

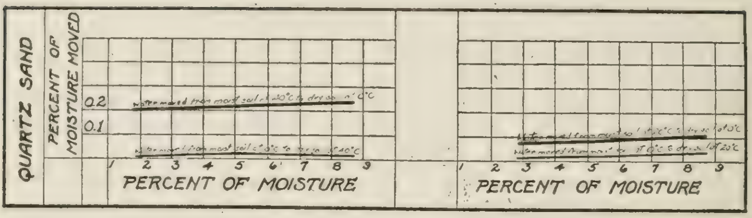
MOVEMENT OF MOISTURE FROM MOIST AND WARM COLUMN TO DRY AND COLD COLUMN OF SOIL, AND FROM MOIST AND COLD COLUMN TO DRY AND WARM COLUMN OF SOIL.

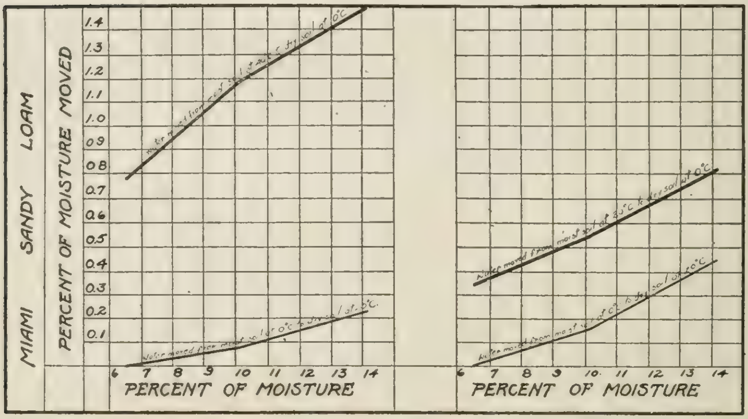
The soil moisture under field conditions exists during the warm period of the year, nearly always in a gradient form. During a long drought the upper surface even dries out, either by its own accord or aided by artificial means. This layer of dry soil formed at the surface is known as mulch. To this mulch is ascribed the important function of conserving the moisture in the soil by its ability to reduce evaporation of water at the surface. It accomplishes this conservation of moisture, it is claimed, by producing a change or break in the capillary connections between itself and the moist soil below.

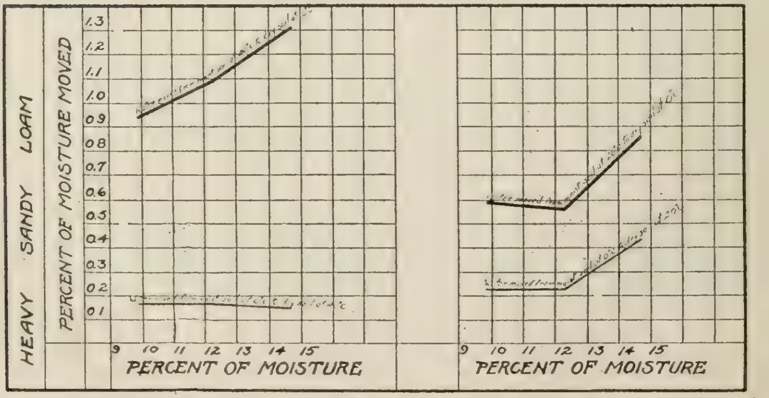
Since, on account of the kinetic energy, the absorptive and adhesive forces of the solid substances decrease with rise in temperature, the interesting question arose whether the dry mulch with an excessively high temperature would absorb moisture from a moist soil with low temperature, even when the capillary connections were ideal. The desire to secure information upon this important and exceedingly interesting point led to the execution of the following experiments: Brass tubes described in the preceding sections, were filled one-half with dry soil and the other half with moist soil, and the two columns were separated only by a circular piece of cheese-cloth in order to facilitate separation of the two columns for moisture movement determinations. The tubes were then inserted in the boxes shown in figure 1, and that portion of the tubes containing the moist soil was kept at 20° and 40° C, and that part which held the dry soil was maintained at 0° C. In another set of tubes these temperatures were reversed. The soils employed were the same as those previously described, namely: quartz sand, light and heavy Miami sandy loam, Miami silt loam, Clyde silt loam and Miami clay. There were three different moisture contents used for each soil, designated as, low, medium, and high. The duration of all experiments was about 8 hours. The numerical data obtained are shown in table 4 below. The accompanying figure 3 represents these same data graphically. Each soil has two charts, the one to the left is for the temperature amplitude of 40° C., and the one to the right is for the temperature range of 20° C. The abscissas, in every case, represent percentage of moisture content, and the ordinates, percentage of water moved either from the moist and warm column to the dry and cold column of soil, or from the moist and cold column to the dry and warm column of soil. The upper curves of each chart represent the percentage of water movement that took place from the moist and warm soil to the dry and cold soil, and the lower curves show the movement of water that occurred from the moist and cold soil to the dry and warm soil. As in the preceding case, the percentage of moisture moved is based upon the difference in percentages of moisture contained in the dry soil at the beginning and end of the experiment.

TABLE 4.—PERCENTAGE OF MOISTURE MOVED FROM MOIST AND WARM COLUMN OF SOIL TO DRY AND COLD COLUMN OF SOIL, AND FROM MOIST AND COLD COLUMN OF SOIL TO DRY AND WARM COLUMN OF SOIL.

		Percentage of moisture.		
Moisture in moist column of soil		1.85	5.30	8.75
Quartz sand.	Movement from moist column at 20°C., to dry column at 0°C	0.0746	0.0879	0.1129
	Movement from moist column at 0°C., to dry column at 20°C	0.0105	0.02131	0.03912
	Movement from moist column at 40°C., to dry column at 0°C	0.2048	0.2210	0.2376
	Movement from moist column at 0°C., to dry column at 40°C	0.0121	0.0160	0.01522
Moisture in moist column of soil		6.497	10.141	14.17
Light sandy loam.	Movement from moist column at 20°C., to dry column at 0°C	0.345	0.550	0.820
	Movement from moist column at 0°C., to dry column at 20°C	0.061	0.163	0.448
	Movement from moist column at 40°C., to dry column at 0°C	0.779	1.18	1.496
	Movement from moist column at 0°C., to dry column at 40°C	0.000	0.08	0.235
Moisture in moist column of soil		9.906	12.30	14.695
Heavy sandy loam.	Movement from moist column at 20°C., to dry column at 0°C	0.592	0.569	0.863
	Movement from moist column at 0°C., to dry column at 20°C	0.215	0.211	0.445
	Movement from moist column at 40°C., to dry column at 0°C	0.937	1.094	1.309
	Movement from moist column at 0°C., to dry column at 40°C	0.168	0.169	0.150
Moisture in moist column of soil		10.89	17.88	18.67
Silt loam.	Movement from moist column at 20°C., to dry column at 0°C	0.687	0.844	0.989
	Movement from moist column at 0°C., to dry column at 20°C	0.411	0.461	0.529
	Movement from moist column at 40°C., to dry column at 0°C	1.413	1.942	2.038
	Movement from moist column at 0°C., to dry column at 40°C	0.347	0.445	0.438
Moisture in moist column of soil		15.349	25.086	36.18
Clyde silt loam.	Movement from moist column at 20°C., to dry column at 0°C	0.429	0.662	0.962
	Movement from moist column at 0°C., to dry column at 20°C	0.100	0.606	0.900
	Movement from moist column at 40°C., to dry column at 0°C	0.814	1.554	2.046
	Movement from moist column at 0°C., to dry column at 40°C	0.042	0.594	0.852
Moisture in moist column of soil		17.05	21.88	23.29
Clay.	Movement from moist column at 20°C., to dry column at 0°C	0.514	0.653	0.923
	Movement from moist column at 0°C., to dry column at 20°C	0.436	0.502	0.796
	Movement from moist column at 40°C., to dry column at 0°C	1.180	1.482	1.552
	Movement from moist column at 0°C., to dry column at 40°C	0.380	0.850	0.873


QUARTZ SAND
PERCENT OF MOISTURE MOVED
0.2
0.1
Water moved from moist soil at 20°C to dry soil at 0°C
Water moved from moist soil at 0°C to dry soil at 40°C
1 2 3 4 5 6 7 8 9
PERCENT OF MOISTURE
Water moved from moist soil at 40°C to dry soil at 0°C
Water moved from moist soil at 0°C to dry soil at 20°C
1 2 3 4 5 6 7 8 9
PERCENT OF MOISTURE


MIAMI SANDY LOAM
PERCENT OF MOISTURE MOVED
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Water moved from moist soil at 20°C to dry soil at 0°C
Water moved from moist soil at 0°C to dry soil at 20°C
6 7 8 9 10 11 12 13 14
PERCENT OF MOISTURE
Water moved from moist soil at 20°C to dry soil at 0°C
Water moved from moist soil at 0°C to dry soil at 20°C
6 7 8 9 10 11 12 13 14
PERCENT OF MOISTURE


HEAVY SANDY LOAM
PERCENT OF MOISTURE MOVED
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Water moved from moist soil at 20°C to dry soil at 0°C
Water moved from moist soil at 0°C to dry soil at 20°C
9 10 11 12 13 14 15
PERCENT OF MOISTURE
Water moved from moist soil at 20°C to dry soil at 0°C
Water moved from moist soil at 0°C to dry soil at 20°C
9 10 11 12 13 14 15
PERCENT OF MOISTURE

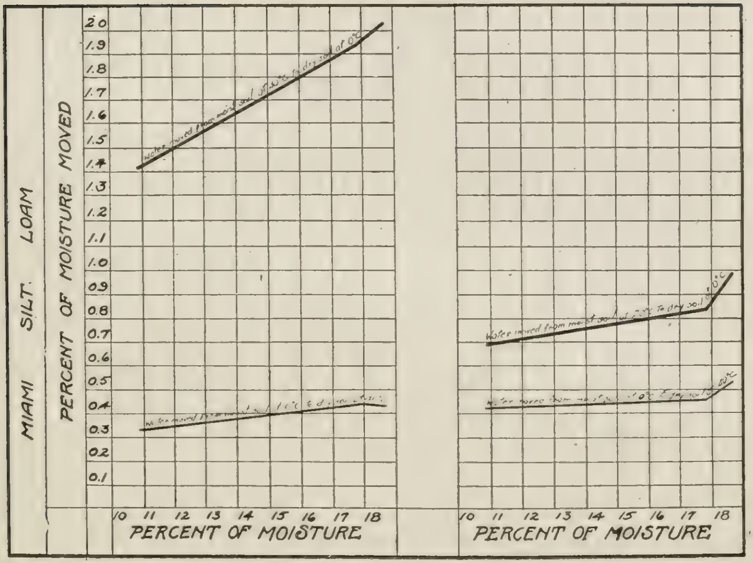


FIG. 4. CURVES SHOWING MOISTURE MOVEMENT FROM MOIST AND WARM COLUMN OF SOIL TO DRY AND COLD COLUMN OF SOIL; AND FROM MOIST AND COLD TO DRY AND WARM COLUMN OF SOIL.

Considering first the numerical values showing the amount of water moved from the moist and warm column of soil to the dry and cold column of soil, which are graphically represented by the upper curve of each chart, it will be seen (1) that this amount is nearly twice as great in the temperature amplitude of 40° as in 20° C., (2) that it is somewhat greater in soils with higher than with lower colloidal content, and (3) that it increases with the rise in moisture content.

By comparing these results with those obtained with column of soils of uniform moisture content, some very striking contrasts are revealed. The previous results show, for instance, that the maximum thermal motion of water occurs at a definite but comparatively low moisture content, and that the value amounts in some cases over 3.50 per cent. The above data, show, however, that the maximum movement of water from the moist and warm column to the dry and cold column of soil, takes place at the highest water content, and that in the majority of cases the percentage of this maximum water translocation is only one-half as great as in the former case.

These apparent differences seem to be easily explainable. The increase of water movement from moist and warm soil to dry and cold soil with rise in water content is natural, and only goes to prove that the water is held by the soil with low moisture content, with a great force, and consequently it cannot be extracted readily and extensively by a greater abstracting force. When the attractive forces of the soil for water are satisfied, and the thickness of the surface and capillary films is increased, then greater quantities of water will be removed by the same abstracting force. The smaller thermal water movement which occurs in the moist

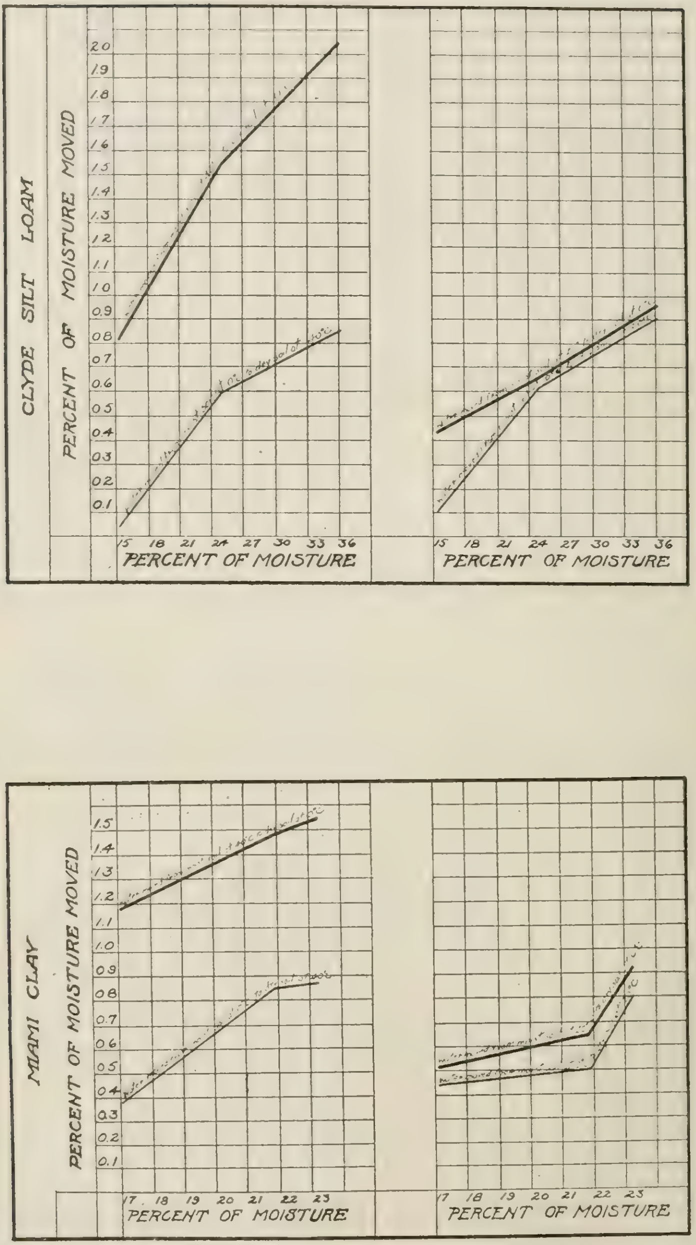


FIG. 4. CURVES SHOWING MOISTURE MOVEMENT FROM MOIST AND WARM COLUMN OF SOIL TO DRY AND COLD COLUMN OF SOIL; AND FROM MOIST AND COLD TO DRY AND WARM COLUMN OF SOIL.

and dry soil than in the soil of uniform moisture content, is due mainly to the cheese-cloth which is placed between the dry and moist columns of soil. Although this cheese-cloth was very thin and had large perforations, yet it prevented the two columns from forming a complete and perfect contact, and consequently the dry soil had to absorb water directly through the cheese-cloth, as well as from the soil.

Another factor which would seem to impede the rate of water movement from moist and warm to dry and cold column of soil is the resistance which the dry soils offer to wetting, due to the air film surrounding the particles and to any oily substance that might be present. The influence of this factor, however, must be extremely small, if any, because when these soils were slightly damped the amount of water moved was generally less or about the same as before. *The common belief that water moves more rapidly in damp than in dry soils is generally exaggerated. When a soil is damped to eliminate the factor of resistance to wetting its absorptive power for water is decreased correspondingly so that one factor tends to counterbalance the other, and at the end the results are about the same.* Moreover the soils which stubbornly resist wetting are not very common.

From the practical standpoint the results of the second part of the present investigation are probably far more important than those of the first part just disscussed. *These results show the remarkable fact that when the dry soil is kept at 20° and 40° C. and the moist soil at 0° C. the dry soil takes up very little if any, water from the moist soil, and that this quantity of water, absorbed decreases with rise in temperature.* As will be seen from the figures the percentage of moisture absorbed by the dry soil at 20° C, is in all cases greater than that absorbed at 40° C. At both amplitudes of temperature, the percentage taken up increases with the colloidal content in the soil, which is natural.

Obviously then, the temperature has a tremendous influence upon the absorptive power of soils for water. This is what might be expected from the laws of kinetic energy. According to this law the energy or motion of the molecules increases with temperature, and consequently the adhesive and absorptive forces of the solid matter for liquids or gases, decreases. These results then, tend to confirm postulate 2 page 14 that the attractive forces of the soil for water decrease with rise in temperature.

The foregoing experimental results and theoretical consideration suggest very strongly that the efficiency of the soil mulches in conserving moisture in the soil is not dependent solely upon their thickness and degree of capillary discontinuity between themselves and the moist soil below, but also upon their temperature. It is well known that the temperature of the surface soils during sun insolation is many degrees higher than that of the air immediately above. In some parts of the world, where the sky is clear and the sun insolation very intense, the surface soil may attain a temperature about 40° C. higher than that of the air about 4 feet from the ground. Even at this Station the surface soil temperature of the mineral soils and especially of the light sandy soils, is very often approximately 15° C. higher than that of the air above. From the surface downward the soil temperature decreases, but in the upper 1 or 2 inches the diminution is far more rapid than at the lower depths, amounting sometimes, and in certain soils, over 10° C. for each inch depth. When the surface soil is disturbed and a mulch is formed its heat conductivity is decreased, and the high temperature attained at the surface is not all conducted downward but is compelled to accumulate on the dry mulch and then is radiated back into space. The difference in temperature between the mulch and the moist soil below is sometimes as high as 10° C. at this Station. At the arid regions this difference must be far greater. This excessively greater temperature of the dry mulch diminishes the adhesive and absorptive forces of the dry soil so that its capacity and intensity to withdraw water from the moist soil below are either entirely prohibited or greatly reduced. The result is that the water is saved from direct evaporation. On the other hand, during the night the soil temperature reverses itself and becomes lowest at the surface and increases with the depth, but its difference between the mulch and moist soil is generally not as great during night as during the sun insolation. Since the attractive and adhesive force of the dry soil and the surface tension of the soil water are increased by the low temperature, the tendency of the soil moisture is to move upwards very energetically. To what extent this movement occurs cannot be stated with certainty because the moisture, not very far below the mulch, is held with a great force and is given up with great reluctancy, unless moisture moves from further depth below and satisfies the absorptive power, and thickens the surface and capillary films.

Furthermore, the amount of water moved will depend upon the temperature gradient, that is, upon the range of temperature between the surface and lower depths. As already stated, this temperature gradient at night between adjacent depths is always small but is most marked during the summer and fall and least during the spring. Any water, however, that the mulch pulls up during the night is certain of being evaporated during the day. *May it not be then that an appreciable amount of water is lost from the soil in this manner?*

Temperature not only tends to conserve moisture in the soil after the mulch is formed but also aids and hastens the formation of this mulch. It has been seen that as the temperature of the moist soil at the upper depth increases the surface tension of the soil water and the adhesive and absorptive forces of the soil, decrease. The upward pulling force, therefore, is diminished, and the water is not brought up with sufficient rapidity to keep the upper layers moist, so that a mulch is formed at the top. The diminution of the surface tension of the soil water at or near the surface is very large during the sun insolation, and far greater than the increase during the night, because during the sun insolation the soil absorbs heat from the sun very rapidly and since the soil is a poor conductor of heat, the heat is allowed to accumulate at the surface and raise its temperature far above that of the next layers.

The foregoing considerations have been deduced from the experimental data, and from the laws of kinetic energy of matter, surface tension of liquids, etc., in their relation to temperature. It is now of great importance as well as of high interest to know if these deductions can be verified experimentally. The type of experiment which the writer probably would have performed to test out whether or not the temperature does tend to conserve moisture in the soil, has fortunately been performed by Buckingham[15] for another purpose. In his studies on the loss of water under arid and humid conditions, Buckingham endeavored to imitate these two conditions in the laboratory. He placed soil in cylinders 48 inches long and 2½ inches in diameter, and provided each cylinder with side tubes at the bottom for the introduction of water. He allowed, by means of an electrical fan, a current of air to be blown over the top surface of the soils. For the arid conditions this current of air was heated, without changing its absolute humidity, to a temperature of about 50° to 60° F. above the room temperature. To imitate also the high surface temperature of soils under the strong sunshine of arid climates, the top inch and a half of the cylinders under the hot air was heated, by heating coils surrounding the cylinders, to about the same temperature as the hot air. The breeze of about 3 miles per hour, was kept going all the time. The heating current was turned on for six hours a day except on Sunday and holidays. For the humid conditions the soils were placed under the current of air at room temperature. Buckingham performed a number of experiments bearing upon this subject and the results he obtained are qualitatively about the same for all of them. The following diagram shows a typical set of results.

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[15] U. S. Dept. of Agr., Bureau of Soils, Bulletin No. 38 (1907).

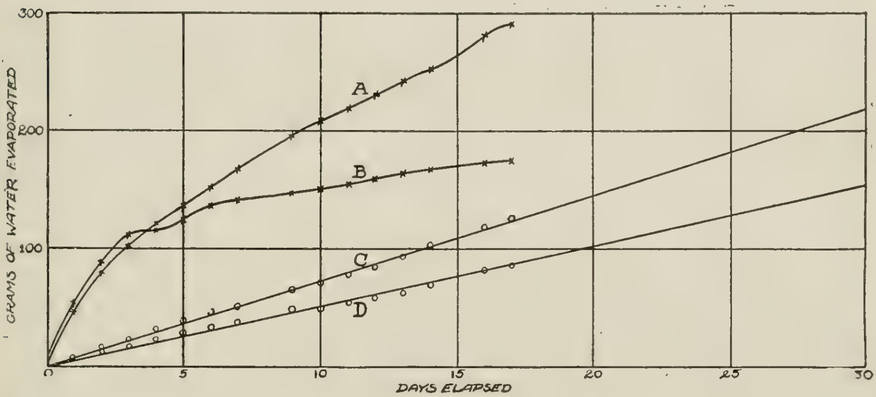

FIG. 5. CURVE SHOWING EVAPORATION OF WATER FROM PODUNK FINE SANDY LOAM WITH TAP WATER; A, SOIL UNDER HUMID CONDITIONS; B, SOIL UNDER ARID CONDITIONS; C, WATER UNDER ARID CONDITIONS; D, WATER UNDER HUMID CONDITIONS. (AFTER BUCKINGHAM.)

An examination of the above figure shows that the loss of water from the soil under arid conditions is much more rapid at first but after about 4 days have elapsed the rate of loss is less under arid than under humid conditions, and continue to be so throughout the duration of the experiment. The rate of evaporation from the soils for the last ten days is 11.2 inches of rain per year under arid conditions and 51.6 inches of rain per year under humid conditions.

Buckingham explains these results under the supposition that a mulch was formed on the soil kept under arid conditions, more rapidly than on the soil kept under humid conditions, and the mulch prevented rapid loss of water from the former. This explanation is correct, of course, in so far as it represents the result of the mulch, but how this mulch was formed and how it was capable of accomplishing this result, it fails to explain correctly. In the opinion of the writer *the above results offer an excellent proof that temperature aids and hastens the formation of a mulch, and tends to conserve the soil moisture in the manner previously set forth.*

This is a remarkable paradox indeed, that temperature which causes the loss of water should also cause its conservation.

THERMO-OSMOSE IN SOILS.

In the course of the foregoing studies on thermal movement of moisture in soils, the question arose: What would happen if on two sides of a soil membrane is placed water of an unequal temperature? Would there be a diffusion of water? And if so would the hot water diffuse towards the cold, or vice versa? The difference in temperature between the two faces of the membrane is analogous to the difference in concentration of solution. If any movement of water occurred in either direction it might be classed under the category of thermo-osmotic phenomena, probably similar to those observed by Lippmann[16] in the case of the gelatine, and golden beaters skin where cold water moved towards the hot. In such an event the soil would act as a semi-permeable membrane in the same manner as in solutions of different concentrations as shown by Lynde[17] and Robinson.[18] It was at first thought that certain of the foregoing data on thermal translocation of water might be attributed to thermo-osmotic phenomena.

Considerable time was expended in endeavoring to devise a method to attack the problem. After several trials the apparatus shown in figure 6 was devised and finally adopted. It consists of a brass tube 11 inches long and 1½ inches in diameter having 4 one-half inch holes, two cap nuts C, and two compressing plungers P. The holes were 1 inch apart at the two ends of the tube, and 3½ inches at the center. The soil whose thermo-osmose or thermo diffusion was to be investigated was placed in the middle of the tube and pressed together by the two compressing plungers. The outer ends of the plungers were loosely connected to the cap nuts and by screwing the latter to the tube the soil in the middle could be pressed to any desired degree. The heads of the plungers were fitted to the tubes tightly and were perforated so as to allow free communication between the soil and water. To prevent the soil from being forced out through these perforations a very fine gauze was inserted on the inner side of each plunger which came in contact with the soil. For maintaining a difference in temperature at the opposite compartments of the soil membrane a wooden box with a partition in the center was employed. The tube was inserted through a hole in the partition and the soil membrane came under this hole and extended equally in both directions. After the two compartments of the wooden box were made water tight either by paraffin or by a compound called "chlorine putty," the two enclosures of the soil membrane were filled with water, and in the inner two holes of the tube were placed two straight glass tubes, and in the outer two holes, two horizontally bent glass tubes of very small diameter. The straight vertical tubes served the purpose of adding water to the compartments and bringing the level of the water to a standard position. On the horizontally bent tubes was intended to read any thermal diffusion of water. The vertical tubes were either left open or closed.

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[16] Comptes rendus 1907, p. 104.
[17] Journal of American Society of Agronomy, Vol. 4, p. 108 (1912).
[18] Results obtained at the Michigan Experiment Station but not as yet published.

The possibility of thermo-osmose was studied in kaolin and in two different kinds of clay, of different thickness of membrane. The temperature amplitudes employed were 0°-20°, 0°- 40°, 0°-60° C. In a large number of trials no thermo-osmose was observed: no movement of water occurred in either direction.

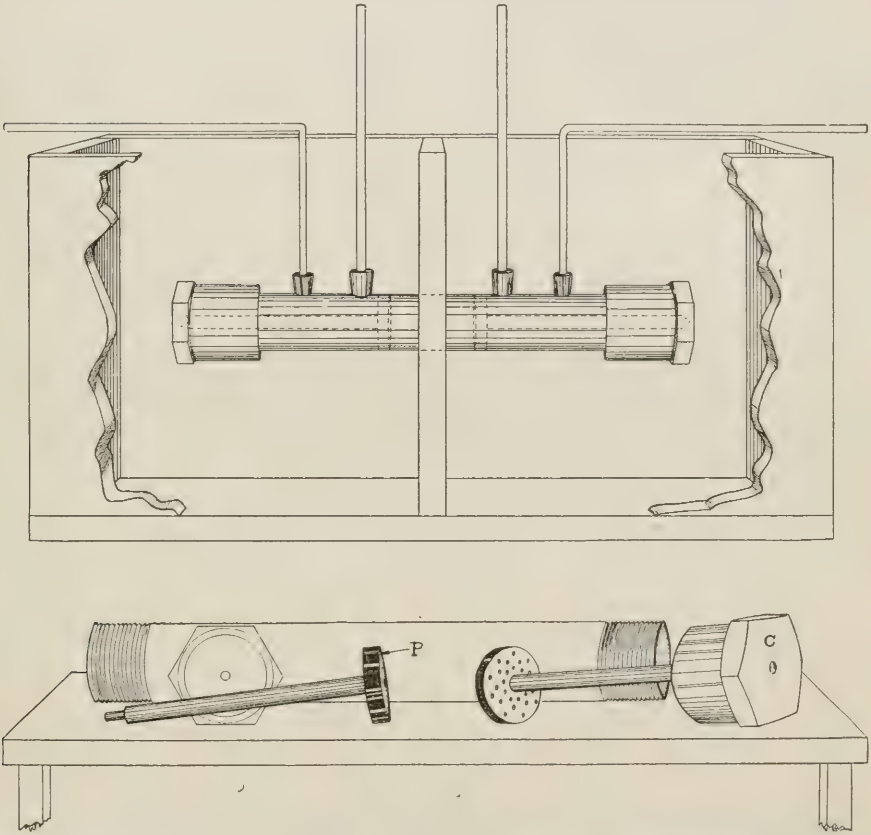


FIG. 6. APPARATUS FOR STUDYING THERMO-OSMOTIC PHENOMENA IN SOILS.

The failure of obtaining any results led to the conclusion that either the method was not sufficiently perfected, or that there is no thermo-osmotic phenomena in soils. In the opinion of the writer the latter conclusion is more probable.

EFFECT OF TEMPERATURE ON THE PERCOLATION OF WATER IN SOILS.

As shown in table 1, the surface tension and viscosity of water decrease with rise in temperature. From these data it is to be expected that the rate of flow of water in soils should increase in direct ratio with temperature. In summer time the rate of percolation should be greater than in winter, before freezing.

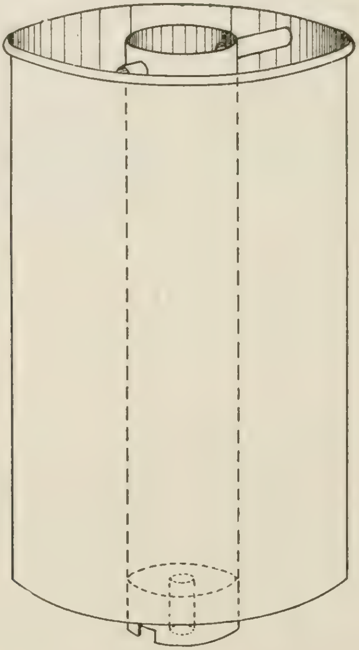


FIG. 7. APPARATUS FOR DETERMINING THE EFFECT OF TEMPERATURE ON THE RATE OF FLOW OF WATER IN SOILS, ALSO THE EFFECT OF TEMPERATURE ON THE WATER-HOLDING CAPACITY OF SOILS.

The only and often cited experiment upon this subject is that of King, in which he attempted to study the influence of temperature upon the rate of percolation of water through a sandy soil only. King found that a rise of temperature of from 9° to 24° C. increased the rate of percolation 50 per cent. Briggs, through calculation, came to the conclusion that these results are precisely those which might have been predicted from the known diminution of viscosity of water with rise in temperature.

Since the subject is of considerable importance and has received really no study, a research of it was undertaken. The method of procedure consisted in keeping a column of soil at a definite temperature and allowing water of the same temperature to percolate. The soil column was contained in a brass tube 14 inches long, and 3 inches in diameter. The soil was placed in the tubes in air dry condition, compacted lightly, and then water allowed to flow through it for three or four days in order to give it a more uniform structure before it was used for experimental purposes. About 2 inches of space was left at the top for a constant head of water pressure. Surrounding the soil tube was a cylindrical compartment 14 inches long, and 10 inches in diameter, and soldered to the soil tube at the bottom as shown in figure 7. In this outer compartment was contained the water at the desired temperature. A channel at the upper part of the soil tube connected the head of water pressure with the level of the outside mass of water. As the percolation in all the soils, except in the sand, is slow, the constancy of the head of water pressure was maintained with no difficulty. The temperature of the water in the outer compartment, and consequently that which flowed through the soil, was changed and maintained to any desired degree, by the addition of either hot water or ice. There are electrical devices which could have been used for this purpose, but it was not considered expedient and necessary, as the above method answered the purpose almost equally well. The soil was allowed to remain and water to percolate through it at any particular temperature for two hours before readings were taken of the velocity of percolation. Inasmuch as the volume of the water in the outer compartment was large and the vessel well insulated on the outside, the temperature remained fairly constant for long periods of time. The temperatures employed were 0°, 10°, 20°, 30° 40°, and 50° C. The classes of soils employed were sand, sandy loam, silt loam, clay loam, clay, and muck. The results obtained are detailed in table 5. They give grams of water percolated during a period of 30 minutes. Figure 8 represents these data in a graphical form.

TABLE 5.—EFFECT OF TEMPERATURE ON THE PERCOLATION OF WATER IN SOILS.

Soil.	Grams of water percolated in 30 minutes.					
	0° C.	10° C.	20° C.	30° C.	40° C.	50° C.
Sand	1215.00	1533.60	1903.50	2496.90	2854.80	3688.50
Sandy loam	17.84	20.92	24.24	26.26	26.61	23.51
Silt loam	5.04	5.86	6.57	6.56	7.48	5.23
Clay loam	12.17	13.85	15.99	17.85	17.26	13.96
Clay	20.10	22.35	24.48	24.91	23.69	17.16
Muck	6.57	7.03	8.61	9.98	9.39	9 06

An examination of these data at once reveals the fact that the rate of percolation of water does not increase in all cases with rise in temperature. On the contrary, with exception of sand, in all the other soils the velocity of flow increases up to a certain temperature and then diminishes again with continued ascent of temperature. The temperature at which the maximum rate of percolation occurs and then commences to descend, is about 30° C. In the case of sand, however, the velocity of flow increases regularly and rapidly with rise in temperature.

Obviously then, the prevalent *a priori* reasoning that the rate of percolation of water in soils increases with increase of temperature is neither

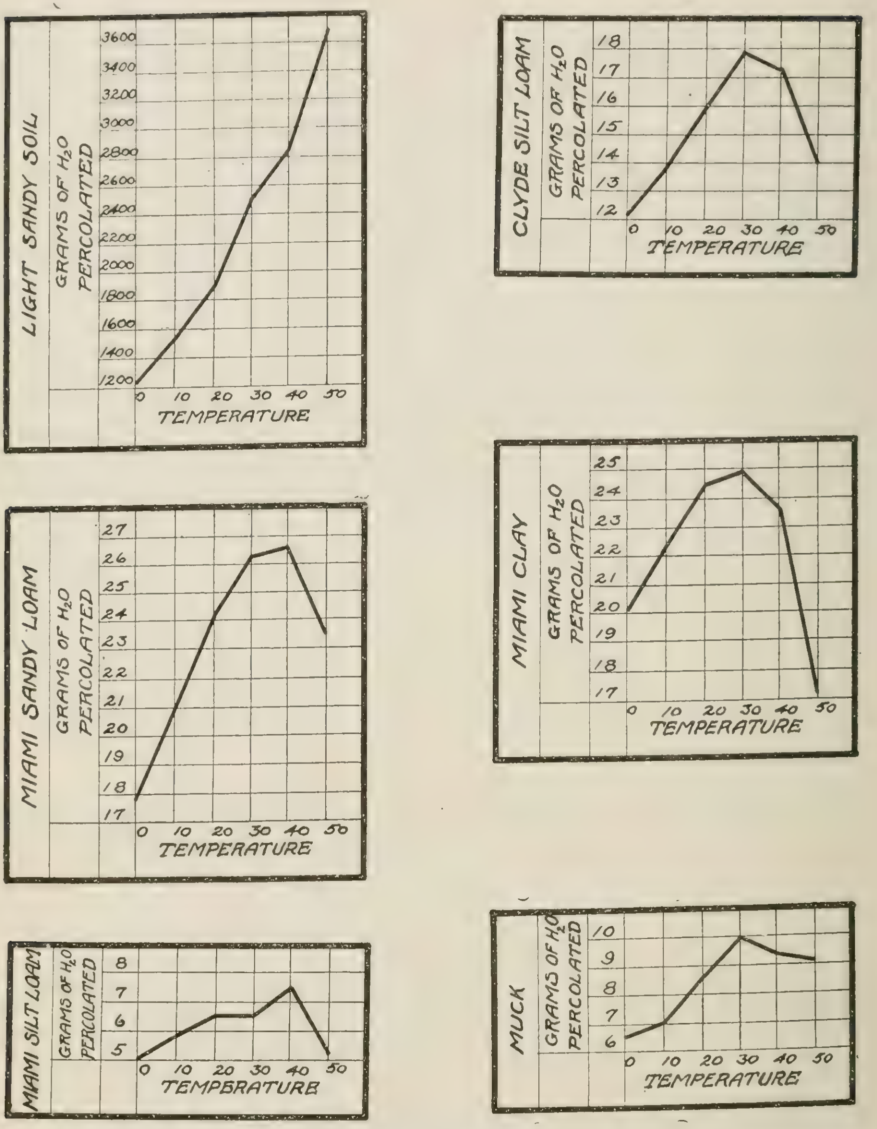


FIG. 8. CURVES SHOWING EFFECT OF TEMPERATURE ON THE PERCOLATION OF WATER IN SOILS.

entirely confirmed nor justified. Evidently, there appears to be some other factor or factors which are influenced more predominately by temperature than the viscosity of water, and succeed, partially or completely, in overpowering the effects of the latter. These opposing factors are to be found (1) in the swelling of the colloidal material present in the soil, and (2) in change in structure of the soil mass, with increase in temperature.

The extensive studies on the subject of colloids have shown that soils contain substance of this nature, and that some classes of soil possess them more abundantly than others. In what structural form they exist in the soil is not as yet definitely known; but evidences seem to indicate very strongly that a part of them at least exists as a gel coating around the solid particles, and another part as individual gel aggregates. Now, it is also known that colloidal substances swell when they absorb water, and that this property of swelling increases with temperature. Their increase in volume at high temperature is probably due, (1) to their inherent constitution, and (2) to the expansion of water they contain.

If soils, therefore, containing colloidal substances are placed in firm and inflexible tubes, such as those used in the present research, in order to oppose any horizontal thrust, and the temperature of these soils is varied, the rate of flow of water through them, will be governed by the viscosity of water, the structure of the soil mass, and the colloidal content of the soil. At about 4° C. the last two factors, and especially the last, favor rapid percolation, but the first factor tends to reduce it. As the temperature rises, the viscosity of water diminishes rapidly and favors the flow of water, but the colloidal material swells and tends to reduce the rate, by filling up the pores through which the water flows. This swelling may not be considerable at the lower temperatures, and allows the reduced viscosity to predominate, so that the velocity of percolation increases with rise in temperature. When a certain temperature is reached, however, the increase in volume, due to swelling of the colloids and expansion of water attains a considerable magnitude, and since the volume of the vessel remains constant, the mass of soil is subjected to a strain: some rearrangement of the particles takes place; many of the pores are closed up, and the rate of percolation commences to decrease. At this temperature, therefore, the factor of swelling predominates over the decreased internal friction of the liquid. With a further increase in temperature this factor of swelling and the consequent closing up of the soil interstices, is augmented. The total result, will be, therefore, just what the experimental data really show. On the other hand, as the soil mass is maintained under a constant strain at the higher temperature, there may occur some radical change in the structure of the soil mass which will favor a high rate of percolation. Such changes were observed in some of the experiments.

In a sandy soil, however, the conditions are different. Here, there are no colloidal substances to swell and close up the pores, and consequently the rate of percolation follows more closely the law of viscosity. This rate, however, is modified by a change in the structure that takes place as the temperature rises. This change in structure in sand, seems to favor a more rapid flow of water. The abnormal velocity of percolation noted in this soil is due to the internal alteration in structure. That a change occurs in structure by varying the temperature is further confirmed by the following observation: When the rate of passage of water was determined say at 20° C. and then at 50° C. and the temperature was brought to 20° C. again, the two readings at 20° C. were not at all the same.

It thus appears that the unexpected trend of the results is explainable by the swelling of the colloidal material, and by the change in structure in the soil mass, with rise in temperature.

The practical question now rises: Would identical results be obtained under natural conditions? This will depend to a large extent upon the structure and composition of the soil. If the soil is compact and contains large amounts of colloidal material the swelling of the latter probably may predominate and cause a decrease in the rate of percolation. If the same soil, however, is loose, and has many crevices, worm holes, etc., the decreased viscosity may predominate and increase the flow of water. On the other hand, it must be remembered that the temperature under field conditions exists practically always in a gradient form, while in the present research it was the same throughout the soil column.

From studies on the flow of water in soils, various investigators have attempted to express the relation of the soil to the movement of water through it, quantitatively. To accomplish this they have assumed that the porous soil is composed of bundles of capillary tubes, and that the velocity of flow of liquid will consequently conform to Poiseuille's formula, which is:

$$v = \frac{\pi}{8} \cdot \frac{ghst}{n} \cdot \frac{r^4}{l}.$$

when v = volume of liquid;
and s = density of liquid;
r = radius of capillary;
n = viscosity of liquid;
l = length of capillary;
g = gravitational constant;
h = head of liquid pressure;

Such an assumption, however, is practically futile. In the first place, Poiseuille's formula was deduced from the ascertained rate of flow of liquid through straight tubes of approximately uniform diameter. The supposed bundles of capillary tubes in the soil are irregular in area, length, direction, and shape, consequently the formula is inapplicable. In the second place, the foregoing research shows that the soil material is dynamic and not static, and that temperature affects its physical constitution so greatly that the velocity of flow of water through it is entirely different from what might be expected from the known physical laws. Hence, it was considered useless to attempt to apply Poiseuille's formula to the foregoing experimental data.

EFFECT OF TEMPERATURE ON THE RETENTION OF WATER BY SOILS.

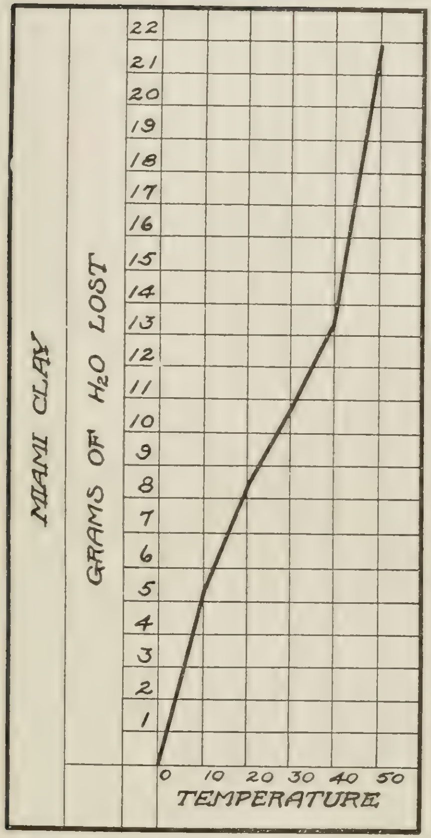
Since the amount of water retained by soils is believed to depend to a considerable extent upon the surface tension of the soil water, and inasmuch as we have seen that the surface tension of water is reduced by increase in temperature, it was decided to conduct an investigation to obtain numerical values of these relations. This research was facilitated by the fact that the same soils of the last section could be used. After the studies on percolation were completed these soils were brought to the temperature of melting ice and allowed to remain at this temperature for about 24 hours to drain. Their temperature then was raised to 50° C. by increments of 10° C., and any water that dripped down during a definite period at any particular temperature was caught and weighed. Preliminary trials showed that during a period of two hours the soils allowed to drain practically all the water that would drain at any one of the temperatures employed. In fact, at the higher temperatures, the soils ceased draining even before the completion of two hours. Throughout this investigation, therefore, the limit of two hours was used for all temperatures and for all soils. Table 6 and the accompanying figure 9 show the results obtained. The table contains also the percentage of water drained and thereby lost, at the different temperatures, based upon the dry weight of the soil.

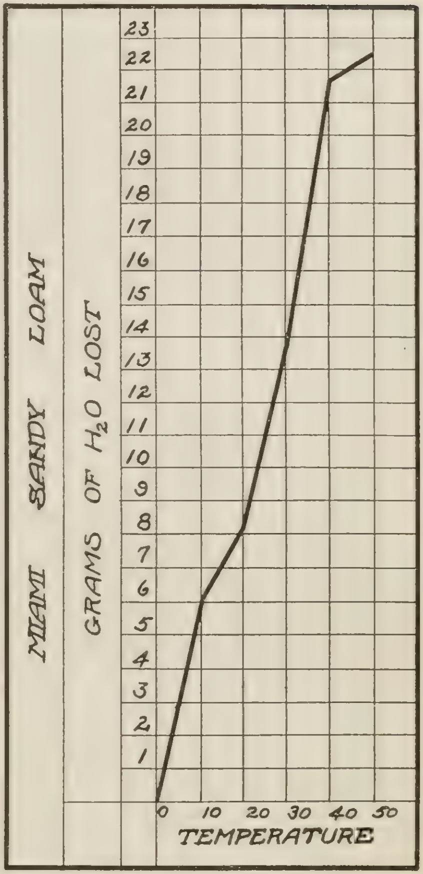
The results show that in the case of the sandy loam, silt loam, clay loam, clay and muck the amount of water drained increases regularly and rather rapidly with increase in temperature. In the case of the sand, however, the quantity drained increases up to the temperature of 30° C. and then commences to diminish with further rise in temperature. The total quantity drained is about the same in the former soils, and about three times greater than in the latter soil.

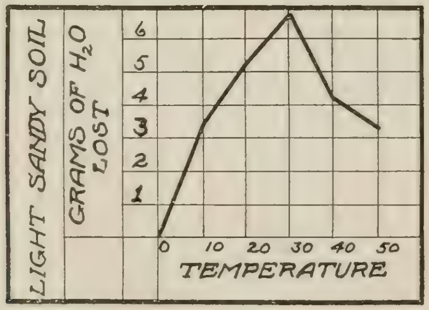
The order of these results complies, in a general way, with what might have been expected, but whether the magnitude of the values, which is rather appreciable, is correct, cannot positively be asserted, because the relation of soil to water and other factors, complicate the problem. According to the figures presented in table 1, the surface tension of water decreases at the rate of about 0.2 per cent per degree Centigrade, so that for every 5° C. the rate decreases about 1 per cent. From this it would appear that the decrease in the water holding capacity of the soils follows the law, but not closely. It is certain, however, that the above quantities of water drained are not wholly due to the decrease in the surface tension of the soil water, but also to two other factors. These are (1) the expansion of the air in the interstices, and (2) the expansion of the soil mass, and consequently to the squeezing out of water. As the water leaves the soil by drainage at the temperature of melting ice, its space is replaced by air. When the temperature of the soil is raised this air, some of which is imprisoned, expands, and produces a sudden pressure throughout the soil mass and forces out or expels some of the free water which accumulates at the lower end of the tube, due to the greater attraction of gravity. As a proof of this may be cited the fact that the

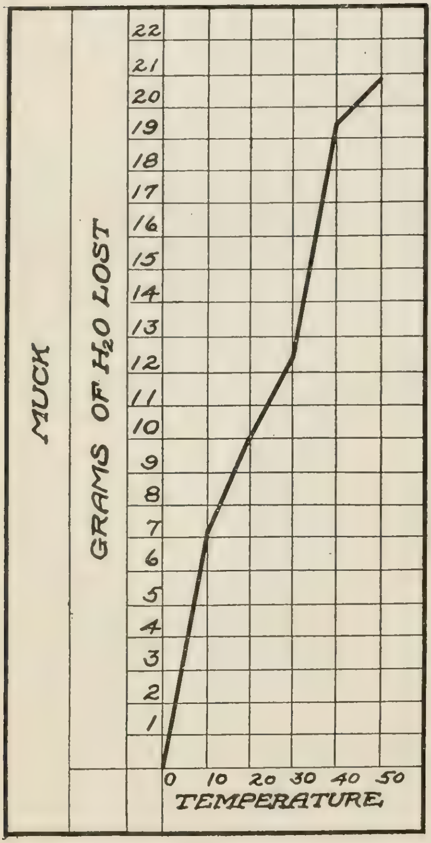
TABLE 6.—EFFECT OF TEMPERATURE ON THE RETENTION OF WATER BY SOILS.

Soil.	Wt. of soil in grams.	Grams of water drained in 2 hours.							Percentage of water drained in 2 hours.					
		0° C.	10° C.	20° C.	30° C.	40° C.	50° C.	Total.	10° C.	20° C.	30° C.	40° C.	50° C.	Total.
Sand	2031	0.0	3.41	5.21	6.89	4.21	3.29	23.01	0.1679	0.2565	0.3393	0.2073	0.1620	1.1330
Sandy loam	1842	0.0	6.10	8.20	13.70	21.63	22.38	72.01	0.3312	0.4452	0.7437	1.174	1.250	3.944
Silt loam	1750	0.0	7.25	10.25	11.45	13.72	17.66	60.33	0.4143	0.5857	0.6543	0.784	1.009	3.4473
Clay loam	1370	0.0	6.30	9.81	13.59	17.79	19.86	67.35	0.4599	0.7160	0.9920	1.299	1.450	4.9169
Clay	1333	0.0	5.42	8.42	10.69	13.37	21.88	59.78	0.4066	0.6316	0.8019	1.003	1.641	4.484
Muck	676	0.0	7.2	10.00	12.50	19.54	20.90	70.14	1.065	1.479	1.849	2.891	3.092	10.376


MIAMI CLAY
GRAMS OF H_2O LOST
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
TEMPERATURE


MIAMI SANDY LOAM
GRAMS OF H_2O LOST
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
TEMPERATURE


LIGHT SANDY SOIL
GRAMS OF H_2O LOST
6
5
4
3
2
1
0
10
20
30
40
50
TEMPERATURE


MUCK
GRAMS OF H_2O LOST
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
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10
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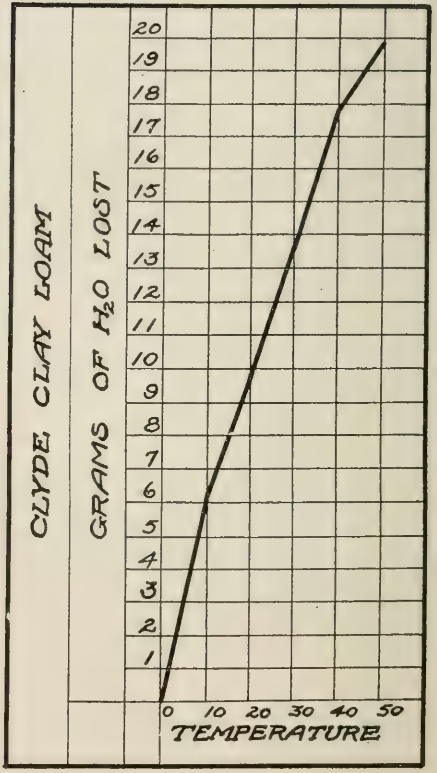
40
50
TEMPERATURE


CLYDE CLAY LOAM
GRAMS OF H_2O LOST
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
TEMPERATURE

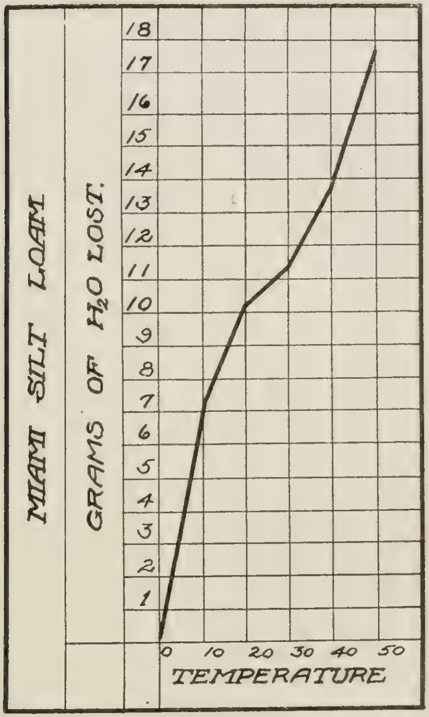


FIG. 9. CURVES SHOWING EFFECT OF TEMPERATURE ON THE RETENTION OF WATER BY SOILS.

greater portion of the water drained at the various temperatures, occurred in the first few minutes when really the soil mass had not as yet acquired to any appreciable degree the external temperature. Furthermore, if the soils were kept say at 50° C. for a considerable length of time and the dripping of water had completely ceased the latter would recommence almost instantly if the temperature was raised even 2 degrees higher. This observation seems to offer the real explanation as to the cause of the diurnal fluctuation of ground water in shallow wells as observed by King[19], and which has been erroneously attributed by many writers to the diurnal change of the surface tension of the soil moisture. There was probably air imprisoned within the soil between the surface and the water level which contracted during the night and expanded during the day and thus caused fluctuations in the ground water.

In the case of the soils with large colloidal content some water is actually squeezed out at the maximum temperatures employed, due to expansion and swelling of the colloidal material. During preliminary tests it was observed, for instance, that if peat and Clyde loam were in the tubes in a rather compact form, water would be forced to the top at the beginning, when the temperature was raised to 50° C.

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[19] U. S. Dept. of Agr., Bul. 5, Weather Bureau, pp. 59-61.

A portion of the water that left the soil at the various temperatures should be attributed to the decreased adhesive power of the soil for water. It is not proper to consider the soil mass itself, as has been done heretofore, as a static and passive skeleton, and as being unaffected by, and irresponsive to temperature, and as playing no part in the capillary movement of water when it is moist. Indeed, the physical properties of the solid soil are affected by temperature as well as those of the liquid, for both classes of matter obey the law of kinetic energy of matter. It is wrong to speak then of the water-holding power of a soil being decreased by rise in temperature because the surface tension of its water is decreased; or that water is pulled upward in a moist soil because only of the curvature of the capillary films.

In view of these considerations, it might be concluded that the diminution of the water holding capacity of a soil due solely to the decreased surface tension of the soil water by temperature is insignificant.

EFFECT OF TEMPERATURE ON THE RATE OF FLOW OF AIR IN SOILS.

Unlike liquids, the viscosity of gases increases with rise in temperature. The velocity of flow of air in soils, therefore, with rise of temperature, should diminish correspondingly. The experiments of Ammon[20] and Wollney[21] have confirmed this conclusion. Ammon has also shown that the actual and calculated results agree. Both of these investigators, however, obtained their results under too abnormal and unnatural conditions, in that they used only dry powdered soils. The foregoing investigation on the velocity of flow of water through soils at the higher temperatures, gave occasion to suspect that the passage of air in dry soils may not be the same in moist soils either in order or magnitude. For this reason, the research presented herewith was undertaken.

The method of procedure consisted of drawing air through a moist column of soil at different temperatures by means of a small tank aspirator. The column of soil was contained in a tube, shown in figure 9, which is 8 inches long, and 8 inches in diameter, and has a small opening at the bottom for forming connections with the aspirator. This soil tube was surrounded by a circular compartment which served as a temperature bath. The soil column was about 5.7 inches high. In order to obtain as uniform conditions of structure and compactness among the different soils as possible, they were placed in the tube in air dry condition, slightly tapped, and water allowed to percolate through them for several days. Following this treatment they were subjected to an alternate drying, wetting, freezing, and thawing. These processes tended to give them a textural and structural condition somewhat similar to that usually found in natural soils under field conditions. The soils were used for the experiment when they contained, what is considered, an average moisture content. As they lost their excess of water the colloidal types contracted in mass and left a space between the sides of the column and the inner wall of the tube. This space was filled with hot paraffin so that

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[20] Forch, a. d. G. D. Agrik—Physik, Bd. 3, S. 209.
[21] Forch, a. d. G. D. Agrik—Physik, Bd. 16, S. 193-222.

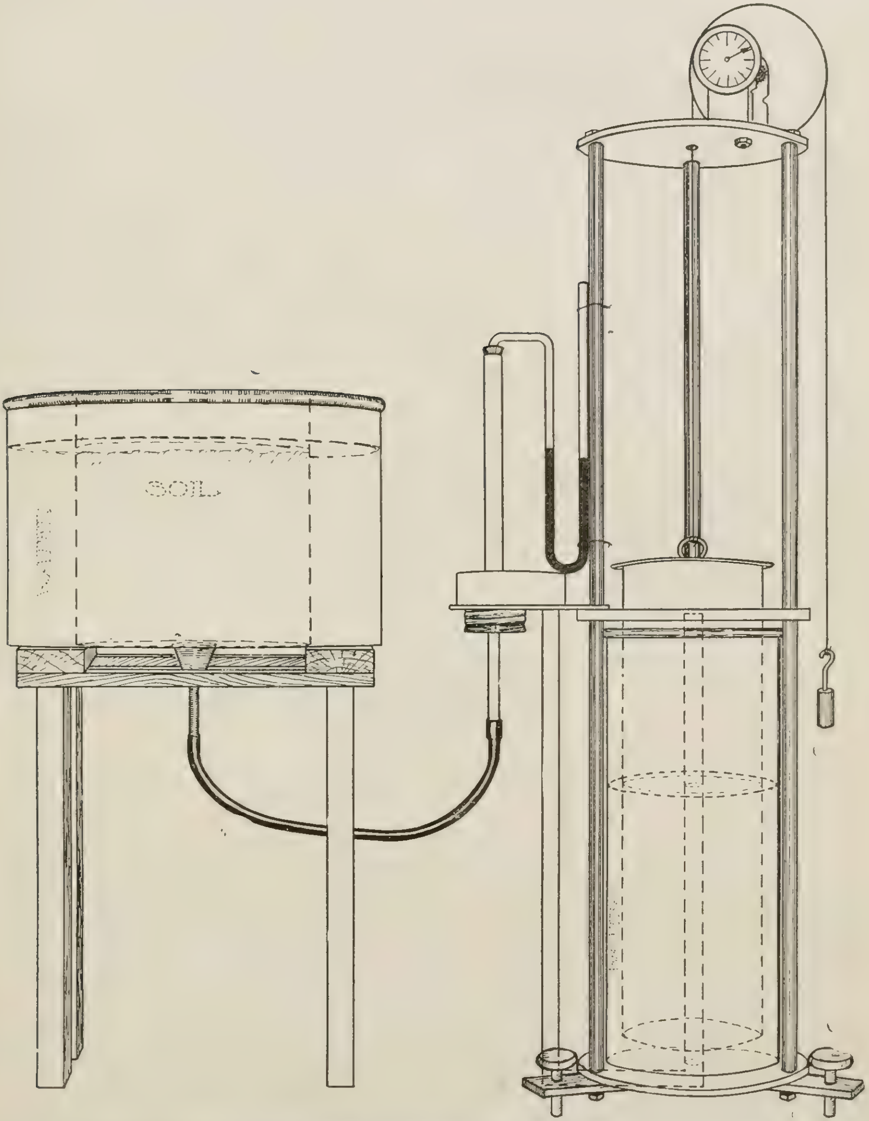

FIG. 10. APPARATUS FOR DETERMINING THE EFFECT OF TEMPERATURE ON THE RATE OF FLOW OF AIR IN SOILS.

the air would be drawn only through the mass of the soil. The rate of passage of air was measured in quartz sand, sandy loam, silt loam, and clay of the Miami series, and Clyde silt loam and peat, at the temperatures of 0°, 10°, 20°, 30°, 40°, and 50° C. The soil column was kept at the same temperature from two to three hours before the transpiration measurements were taken.

The aspirator apparatus employed was similar to that of King's, with few modifications. This apparatus is shown also in figure 10. It consists of a sheet-galvanized iron can 15 inches high, and 5 inches in diameter, inverted over water into another can 14 inches high, and 6½ inches in diameter. The suction tube is ½ inch in diameter and 14½ inches high inside, and 16 inches high outside of the fixed can. The aspirator bell is attached to a fine brass wire which runs over a 6¼ inch grooved metallic pulley, to a weight. The weight employed was sufficient to produce a suction of 2 mm. pressure of mercury. The pressure was read on the manometer. The volume of the aspirator bell was calibrated with air. This was done by adding a definite quantity of water into the outer or fixed can, and then allowing the aspirator bell to come to position, and measuring the volume of air displaced by water in a gas burette. The volume of air displaced is the reciprocal of the volume of air drawn in, for the same water level in the tank. Many preliminary trials showed that four liters of water in the tank gave an air displacement of 2650 cc. on the aspirator bell. In all the experiments, therefore, this quantity of water in the fixed can was used as a standard, and the relative rate of flow of air through soils was measured by noting the time required for 2650 cc. of air to pass through the column of soil. The results obtained are shown in table 7 and on the accompanying figure 11.

TABLE 7.—EFFECT OF TEMPERATURE ON THE RATE OF FLOW OF AIR IN SOILS.

Soil.	Time required for 2650 c.c. of air to pass through soil column.					
	0° C.	10° C.	20° C.	30° C.	40° C.	50° C.
	Min.	Min.	Min.	Min.	Min.	Min.
Quartz sand	1.45	1.50	2.00	2.12	2.28	2.50
Sandy loam	1.40	2.00	2.45	3.37	4.30	10.35
Clyde silt loam	11.00	15.20	18.30	21.20	29.30	41.20
Clay	11.50	15.00	18.00	26.00	31.00	33.00
Peat	13.30	16.40	20.15	20.40	27.30	38.40

The preceding results show that the rate of passage of air through soils decreases inversely with temperature. This is in conformity with the law of viscosity of gases as far as the order is concerned, but not in magnitude. The above velocity of transpiration is governed not only by the internal friction of the gas, but also by the swelling of the colloidal material at the higher temperatures which closes up the pores, and impedes the flow. This fact is very strikingly illustrated by the abnormal decrease in flow at the higher temperatures. The abnormal decrease at the higher temperatures, however, is also partly due to the change in structure brought about by temperature and by the transpira-

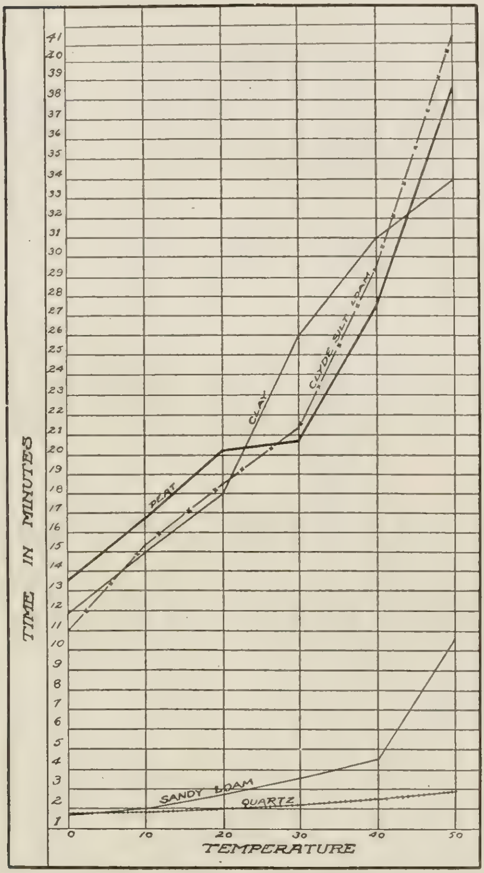

FIG. 11. CURVE SHOWING EFFECT OF TEMPERATURE ON THE RATE OF FLOW OF AIR IN SOILS.

tion of air. As the latter is sucked through the column of soil, some rearrangement of particles undoubtedly occurs. This change in structure sometimes causes either an increase or decrease in the flow of air very suddenly.

The foregoing transpiration data may be expressed also as transpiration constant for any soil and for any particular temperature. By a transpiration constant is meant the number of cubic centimeters of air which would in one second, flow through 1 cm^2 of cross section of a layer of soil 1 cm. thick, if the pressure were 1 mm. of mercury greater on one side of the layer than on the other. The following example will make clear how this transpiration constant can be computed. Suppose that 2650 cc. of air are drawn by the aspirator through a layer of soil 326.8 cm.^{2} in area and 14.7 cm. thick in 105 seconds by a suction of 2 mm. of mercury. The total flow per second is 2650 ÷ 105 or 25.2 cc. per second. The flow through each square centimeter is 25.2 ÷ 326.8 or 0.077 cc. per second. The pressure gradient is 2 mm. in 14.7 cm. or 0.13 mm. per centimeter. Therefore the flow per second through each square centimeter for a gradient of 1 mm. per centimeter would be 0.077 ÷ 0.13 or 0.59 cc. By applying this form of computation to the foregoing experimental data the following figures are obtained.

TABLE 8.—TRANSPIRATION CONSTANT OF SOILS AT DIFFERENT TEMPERATURES.

Soil.	0° C.	10° C.	20° C.	30° C.	40° C.	50° C.
Quartz sand	.590	.567	.497	.452	.403	.351
Sandy loam	.596	.497	.361	.275	.221	.093
Clyde silt loam	.090	.064	.053	.046	.034	.024
Clay	.084	.066	.055	.038	.032	.030
Peat	.073	.059	.049	.084	.038	.025

As would be expected from the experimental results presented in table 7, the transpiration constant is greatest in soils with least colloidal matter, and decreases regularly, and in many cases very rapidly, with rise in temperature.

EFFECT OF TEMPERATURE CHANGES ON THE AERATION OF SOILS.

Unquestionably the aeration of soils is one of the most important problems in soil physics; yet strange to say, it has never been studied experimentally from the temperature point of view. This lack of experimental study is mainly due to the prevalent notion that temperature changes occasion very little, if any, influence on the process of soil areation, because of the small cœfficient of gas expansion which amounts only to 1/273 per degree Centigrade. It is reasoned that since the average diurnal fluctuation of temperature to the depth of 12 inches is not very marked, the volume of gas diurnally exchanged in the upper one cubic foot of soil, is small. Thus King[22] has calculated that the soil ventilation due to diurnal changes in soil temperature will range from 0 up to possibly 20 cubic inches per square foot. Ramann[23], in discussing the subject, makes the following statement: "The influence of temperature fluctuations on the volume of the soil air is not appreciable, and occurs only in the upper layers of the soil. Since the coefficient of expansion of gas is only 1/273 per degree Centigrade, and inasmuch as the temperature fluctuations to the depths of from 4 to 8 inches are small, the diurnal exchange of gas is consequently small."

The problem was subjected to an experimental study and the results obtained show the remarkable fact that temperature has a tremendous influence upon the aeration of soils, and that this influence is due to two other factors besides the mere expansion of gases.

The general method of investigating the problem consisted in heating a definite volume of dry or moist soil to different temperatures and measuring (1) the volume of gas expelled, and (2) the pressure exerted. The volume of gas was measured over water in a gas burette, which is shown on figure 12, and the pressure was measured under mercury on the manometer shown also on the same figure. The soil was contained in a brass tube 8 inches long, and 1½ inches in diameter, closed at one end with a solid rubber stopper, and the other, with a single holed rubber stopper,

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[22] Physics of Agriculture, p. 208 (1901).
[23] Bodenkunde, p. 386 (1911).

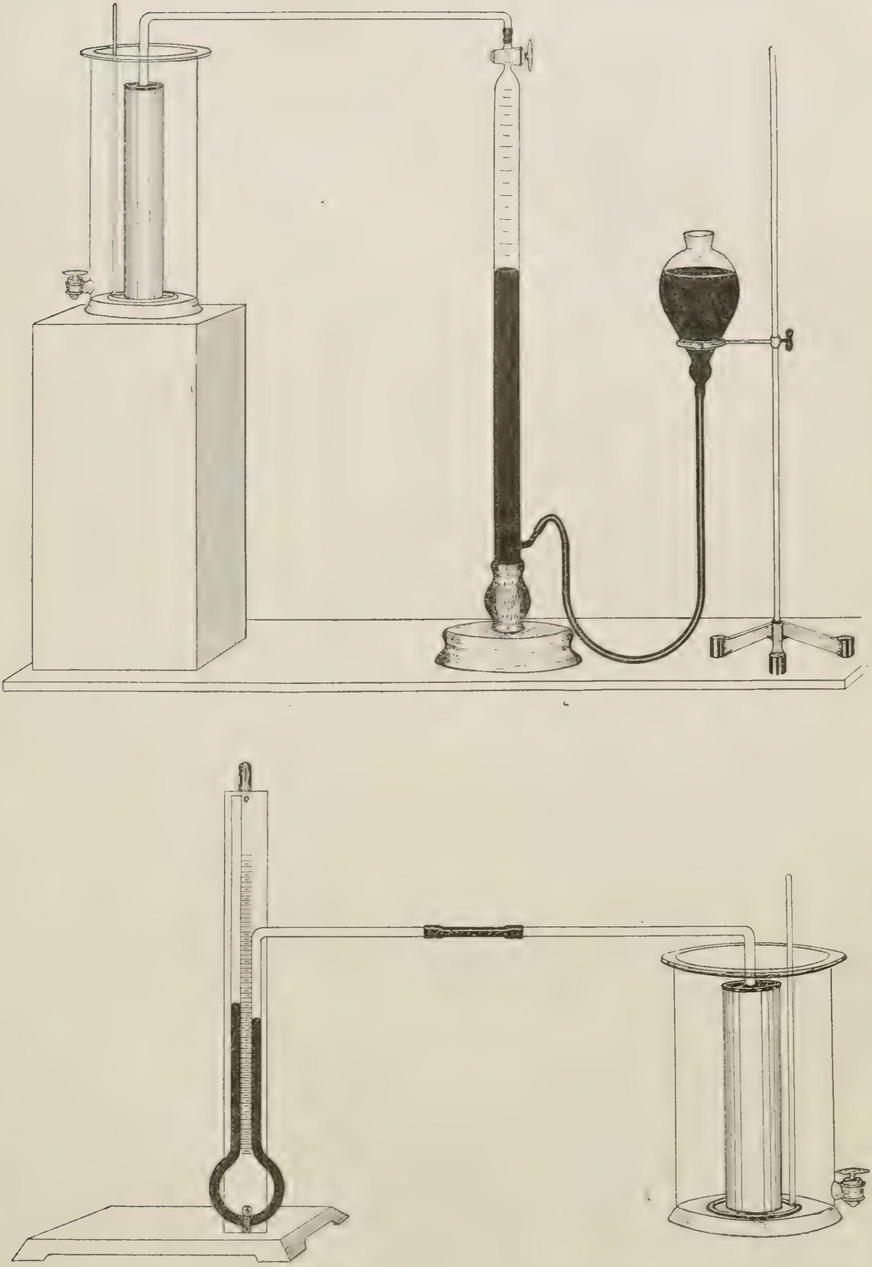


FIG. 12. APPARATUS FOR DETERMINING THE AMOUNT OF GAS EXPELLED AND ITS EXERTED PRESSURE, FROM SOILS AT DIFFERENT TEMPERATURES.

TABLE 9.—EFFECT OF TEMPERATURE ON THE AMOUNT OF AIR EXPELLED FROM AIR DRY SOILS.

Name of soil.	Dry wt. of soils.	Percentage porosity.	Air expelled from soil contained in tube of 152 c. c. capacity.					Total 0-50° C.	Theoretical increase for each 10°C.	Air that would be expelled from one-half cubic foot of soil.					Total 0-50° C.	Theoretical increase for each 10°C.
			0-10°C.	10-20°C.	20-30°C.	30-40°C.	40-50°C.			0-10°C.	10-20°C.	20-30°C.	30-40°C.	40-50°C.		
			c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.
Quartz sand.....	212.5	46.6	3.2	3.5	3.7	4.0	4.9	19.30	2.59	298.2	326.2	344.8	372.8	456.7	1798.7	241.7
Sandy loam......	211.9	45.8	3.1	3.4	3.6	4.0	5.0	19.10	2.55	288.5	317.4	335.0	372.2	465.3	1778.4	237.6
Silt loam........	172.0	55.8	4.1	4.0	3.9	4.0	4.5	20.5	3.10	382.0	372.7	363.4	372.7	419.3	1910.1	289.5
Clyde silt loam...	166.0	53.0	3.9	3.6	4.0	4.4	5.4	21.3	2.95	363.1	335.2	372.4	409.7	502.8	1983.2	275.0
Clay............	178.4	51.3	4.0	3.5	3.6	3.7	4.5	19.20	2.85	372.5	325.9	335.2	244.5	419.0	1797.1	266.3
Peat............	90.0	52.3	4.5	4.3	4.4	4.7	5.4	23.3	2.91	419.1	400.5	409.8	437.8	503.0	2167.5	271.4
Empty tube.....	00.00	109.0	6.4	6.5	6.3	6.2	6.1	31.0	5.57	596.2	605.5	586.9	577.6	568.2	2934.4	518.7

TABLE 10.—EFFECT OF TEMPERATURE ON THE AMOUNT OF AIR EXPELLED FROM MOIST SOILS.

Name of soil.	Dry wt. of soil, grams.	Per cent. moisture.	Per cent porosity.	Air expelled from soil contained in tube of 152 c. c. capacity.					Total.	Theoretical increase for each 10° C.	Air that would be expelled from one-half cubic foot of soil.					Total 0-50° C.	Theoretical increase for each 10° C.
				0-10°C.	10-20°C.	20-30°C.	30-40°C.	40-50°C.			0-10°C.	10-20°C.	20-30°C.	30-40°C.	40-50°C.		
				c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c
Quartz sand.................	187.0	7.02	45.40	3.5	3.6	3.9	4.7	5.9	21.60	2.52	326.1	335.4	363.3	437.9	549.6	2012.3	235.5
Sandy loam..................	162.2	11.00	48.18	3.1	3.8	4.1	4.5	6.0	21.50	2.68	288.8	354.0	382.0	419.3	559.0	2003.1	250.0
Silt loam....................	144.2	18.6	46.98	3.5	3.6	4.6	5.0	6.1	22.80	2.62	325.7	335.0	428.1	465.3	567.6	2121.7	243.7
Clyde silt loam.............	106.5	27.09	53.23	3.8	3.9	4.3	5.0	6.4	23.40	2.96	354.0	363.4	400.6	465.9	596.3	2180.2	276.0
Clay.........................	111.6	25.28	50.32	3.9	4.1	4.6	5.4	6.5	24.50	2.80	363.2	381.8	428.3	502.8	605.3	2281.4	261.0
Peat.........................	4.9	91.97	38.63	5.0	5.5	6.0	7.0	8.5	32.00	2.15	465.9	512.5	559.0	657.2	792.0	2981.6	200.4
Empty tube..................	....	....	100.00	5.8	5.9	5.8	6.0	5.7	29.2	5.57	596.2	605.5	586.9	577.6	568.2	2720.2	518.7

TABLE 11.—EFFECT OF TEMPERATURE ON THE AMOUNT OF PRESSURE EXERTED BY MOIST SOILS.

Name of soil.	Dry wt. of soil. grams.	Percentage of moisture,	Percentage of porosity	Pressure exerted by soils contained in tube of 152 c. c. capacity.					Total.	Pressure that would be exerted by one-half cubic foot of soil.					Total.
				0-10°C. Atms.	10-20°C. Atms.	20-30°C. Atms.	30-40°C. Atms.	40-50°C. Atms.	Atms.	0-10°C. Atms.	10-20°C. Atms.	20-30°C. Atms.	30-40°C. Atms.	40-50°C. Atms.	Atms.
Quartz sand.....	187.0	7.02	45.40	0.0342	0.0414	0.0454	0.0579	0.6908	0.2480	3.187	2.859	4.229	5.394	6.436	23.105
Sandy loam......	162.2	11.00	48.18	0.0342	0.0408	0.0460	0.579	0.0723	0.2626	3.187	3.800	4.291	5.395	6.498	23.171
Silt loam........	144.2	18.16	46.98	0.0342	0.0421	0.0460	0.0605	0.0710	0.2592	3.187	3.924	4.291	5.517	6.498	23.418
Clyde silt loam...	106.5	27.09	53.23	0.0363	0.0447	0.0487	0.0605	0.0723	0.2626	3.379	4.163	4.530	5.633	6.734	24.439
Clay............	111.6	25.28	50.32	0.0355	0.0441	0.0480	0.0605	0.0710	0.2592	3.308	4.105	4.472	5.635	6.616	24.136
Peat............	4.9	91.97	38.63	0.0460	0.0552	0.0671	0.0776	0.0894	0.3355	4.291	5.150	6.253	7.234	8.337	31.265
Empty tube.....	....	....	100.00	0.0342	0.0368	0.0355	0.0368	0.0368	0.1802	3.187	3.432	3.309	3.432	3.432	16.79

which contained a bent glass tube to be connected to the gas burette. The soil column in the tube occupied a space of 152 cubic centimeters, and was about 6.5 inches in length. The length was calculated to represent the depth that the upper surface of soil is tilled, and in which the amplitude of temperature is most marked. There were six different classes of soil used, namely: quartz sand, and sandy loam, silt loam, and clay of the Miami series, and Clyde silt loam and peat. All these soils, both in the dry and moist condition, were passed through a sieve, mixed well, and compacted in the tube as uniformly as possible. The packing was done by allowing the tube to fall in a vertical position a certain number of times from a definite height. The soil was heated to any desired temperature by varying the temperature of the water contained in the vessel in which the soil tube was placed. There were six different temperatures employed, 0°, 10°, 20°, 30°, 40°, and 50° C. These temperatures are within the limits of the temperature changes that occur in the bare soil between winter and summer, and between day and night in succession, or at intervals of a few days. The soil was kept at the same temperature until no more gas was expelled or pressure exerted. In the case of the moist soil the equilibrium was attained in about 30 minutes, but in the case of the dry soils, a somewhat longer time was required. It is doubtful, however, whether all the air was expelled, even when equilibrium was established, because there are films or small bubbles of air which adhere with great tenacity to particles, and especially to those coated with oily substances. Moreover, some air is imprisoned and cannot escape. Some very slight irregularities which will be noticed in some of the results, may be attributed to these factors. But the error resulting from the difficulty of expelling all the gas must relatively be very small on account of the large volumes of gas expelled. The following tables and diagrams represent the results obtained. Table 9 contains the ob-

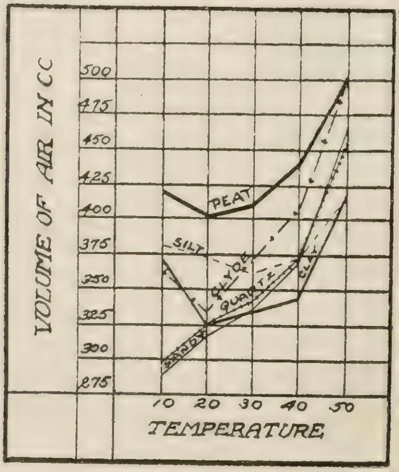


FIG. 13. CURVE SHOWING THE EXPULSION OF AIR FROM ONE HALF CUBIC FOOT OF AIR DRY SOIL AT DIFFERENT TEMPERATURES.

tained and calculated data for the volume of gas expelled from the dry soils. Table 10 contains the identical data for the moist soils. These tables are accompanied by figures 13 and 14 respectively. Table 11 represents the amount of pressure exerted by the moist soils only. The data of this table is shown on figure 15.

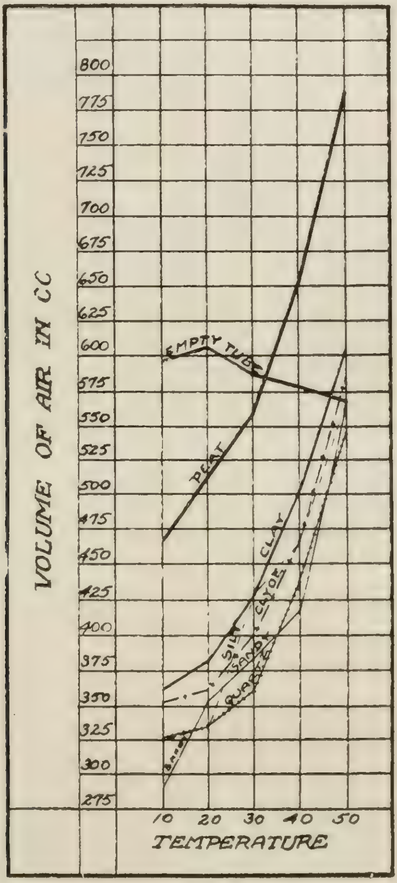
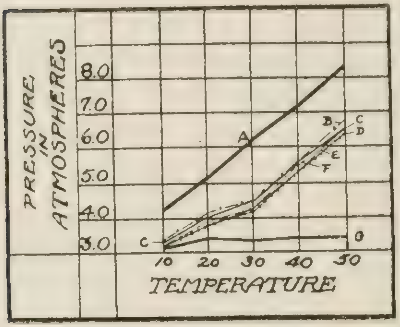


FIG. 14. CURVE SHOWING THE EXPULSION OF AIR FROM ONE HALF CUBIC FOOT OF MOIST SOIL AT DIFFERENT TEMPERATURES.



A—Peat.
B—Clyde Silt Loam.
C—Clay.
D—Quartz.
E—Sandy Loam.
F—Silt Loam.
G—Empty Tube.

FIG. 15. CURVE SHOWING THE PRESSURE EXERTED BY AIR IN ONE HALF CUBIC FOOT OF MOIST SOIL AT DIFFERENT TEMPERATURES.

Before entering into the discussion of the data presented in the preceding tables and charts, an explanation of their form of presentation is necessary. The first eleven columns of tables 9 and 10 show the weight of the soils contained in the tube, the percentage of pore space, etc., and the actual number of cubic centimeters of air obtained at the various temperatures. The last seven columns to the right show the same experimental results reduced to the volume of air that one-half cubic foot of soil would give, provided it had the same percentage of pore space as the soil in the tube. This basis makes the figure more practicable and more comprehensible. As will be seen, the volumes are not reduced to the standard condition of temperature and pressure, which can be done by the use of the formula of $V_0 = V \frac{P}{760\ (1 + 0.00367t)}$ or $V_0 = V \frac{P - M}{760\ (1 + 0.00367t)}$ where V_0 is the volume under standard conditions, V the observed volume, P the pressure expressed in millimeters of mercury, t the observed temperature, and M the vapor pressure of the liquid, because the data as given above represent more closely the true state of affairs. As will be shown later, the amount of gas expelled or pressure produced, are very greatly influenced by the aqueous vapor present, and if the results were reduced to the standard conditions, this factor would have to be eliminated. The principal object of the research is to ascertain to what extent temperature affects the ventilation of soils in *toto*, and not necessarily the increase of volume of the pure gases in the soil. Nor are the data reduced to any common pressure. The atmospheric pressure varied about .20 inches on the barometer for different experiments. Repeated tests showed, however, that the error resulting from the difficulty of expelling all the gas from the soils, exceeds that due to the small variations in the atmospheric pressure. Hence, the changes in atmospheric pressure have been disregarded in the calculation of the preceding results. The first ten columns of table 11 show the actual pressure in atmospheres of mercury that the experimental soils produced, and the last seven columns represent the same data reduced to the basis of one-half cubic foot of soil, the percentage of pore space in the experimental soil being taken as a basis.

With these explanatory remarks in mind, the discussion of the data may now be undertaken. Disregarding for the present table 9 with the dry soils, and considering only table 10 with the moist soils, *it will be found that temperature exerts a great influence on the aeration of soils.* The quantity of gas that would actually be exhaled or inhaled by raising the temperature of the upper half cubic foot of soil from 0° to 10° C., amounts to 326.2 cc. in the quartz sand, 288.8 in sandy loam, 325.7 in silt loam, 354.0 in Clyde silt loam, 363.2 in clay, and 465.9 in peat. These volumes increase very regularly and markedly with rise in temperature so that at the temperature elevation of from 40° to 50° C. they amount to 549.5 cc. in quartz sand, 559.0 in sandy loam, 567.6 in silt loam, 596.3 in Clyde silt loam, 605.3 in clay and 792.0 in peat. It must be noted that this increase in volume with a rise in temperature is contrary to the law of Charles which states that "providing the pressure remains constant the volume of a gas will change 1/273 for each degree of change of temperature." In the present case the pressure, which is the atmospheric, remained constant throughout the duration of the experiment. According to this law the results should follow the formula $V = V_0 (1 + at)$ in which V_0 represents the volume of the gas at 0° and V the volume at a temperature of t and a = 1/273, so that the increase in volume for every rise of 10° C. should be the same for all equal temperature increments. The last column to the right shows the theoretical increase in volume of air contained in the total pore space of the upper half cubic foot of soil, for every raise of 10° C. up to 50° C. By comparing this theoretical increase in volume with the actual increase obtained at the different temperature elevations, the remarkable fact becomes at once evident that the latter not only rises with every increment of temperature, while the former remains the same, but also the difference between the two is very marked even at the temperature elevation of from 0° to 10° C., and that it is gradually accentuated with further rise in temperature so that at the temperature elevation of from 40°-50° C. it is, in most cases about 4 times greater than that at 0°-10° C. For example, at the temperature elevation of from 0° to 10° C, the difference in volume increase between the actual and theoretical is 90.6 cc. for quartz sand, 38.8 for sandy loam, 82.0 for silt loam, 78.0 for Clyde silt loam, 102.2 for clay, and 265.5 for peat. While at the temperature elevation of from 40° to 50° C. the difference is 314.1 cc. for quartz sand, 309.0 for sandy loam, 323.9 for silt loam, 320.3 for Clyde silt loam, 344.3 for clay and 592.6 for peat. It will also be seen that the increase in volume of the actual results is 50 per cent greater from the rise of temperature of from 40° to 50° C. than that from 0° to 10° C., while the increase in volume of the theoretical results is the same at both increments of temperature.

The horizontal line to the left headed "empty tube" contains some very important information in connection with what has been said above. This column contains the increase in volume of the air enclosed in an empty tube of exactly the same capacity as that contained the soils. The air in this tube was dried by heating the tube to 100° C. and then cooling it gradually to 0° C. and allowing air to pass either through

$CaCL_2$ or H_2SO_4 before it entered the tube. This procedure had an object in view which will be revealed subsequently. Since the tube was empty its "porosity" was 100 per cent. Reducing, for sake of comparison, its volume to that of an empty half-cubic foot, the increase in volume of the air by increments of 10° C. will be found at the bottom of the right hand half of the table. An examination of these results show that they follow the law of Charles in that the increase in volume is the same for equal raise in temperature. The total increase in volume from 0° to 50° C. is greater than that of quartz sand, sandy loam, silt loam, Clyde silt loam, and clay but is 261.4 cc. less than that of peat. *This is indeed very interesting, the half cubic foot tube filled with moist peat and having a pore space of 5470 cc. should give a greater increase in volume of air from a temperature rise of from 0° to 50° C. than the same half cubic foot tube containing nothing but dry air, and having a pore space of 14,160 cc.* On the other hand, when the air of this empty tube is not previously dried, the increase in volume for every 10° C. raise of temperature ascends exactly as that of the moist soils, and that the total volume increase is far greater than that of all the soils, including peat. This difference in the results between the dry and moist air in the tube suggested the explanation as to the cause of the difference between the actual and calculated results already considered.

Taking up now table 10 with the air dry soils, it will be seen that the results follow in order those of the moist soils. The only difference is that in the former the actual increase in volume with the various increments of temperature is not so marked and so regular, and that the total volume increase is not so great, as in the latter. An explanation for these apparent variations will be offered subsequently.

Table 11 and the accompanying figure 14 show, as already stated, the pressure exerted in atmospheres of mercury by the moist soils contained in the tube of 152 cc. capacity, or in half cubic foot (14,160 cc.) tube. *An examination of these data will at once reveal the fact that the pressure produced by the increase in volume with rise in temperature is tremendous.* The amount of pressure that would actually be produced by raising the temperature of the upper half cubic foot of soil from 0° to 10° C. amounts 3.187 atmospheres in quartz sand, 3.187 in sandy loam, 3.187 in silt loam, 3.379 in Clyde silt loam, 3.308 in clay, and 4.291 in peat. This pressure increases in all the soils regularly and rapidly with a rise in temperature so that the temperature elevation of from 40° to 50° C. the pressure exerted by the quartz sand is 6. 436 atmospheres, by the sandy loam 6.498, by the silt loam 6.498, by the Clyde silt loam 6.734, by the clay 6.616 and by the peat 8.337. Evidently the pressure increases as abnormally as the volume, and consequently both must possess a common cause. Theoretically, the amount of pressure produced by the various 10° C. increments must be the same as the results of the empty tube show, which were obtained from dried air.

The foregoing abnormalities, both in the volume and pressure increase with a continued rise in temperature, and the great deviation from the theoretical volumes as calculated from the porosity of the soil, are due (1) to the pressure or expansion of the water vapor, and (2) to the gases absorbed by the soils and given off at the various temperatures.

As already mentioned, water is transformed into vapor by the application of heat and the quantity vaporized increases with rise of temperature, and is usually deduced from the pressure exerted. The following table shows the great influence that temperature has upon the vapor pressure.

TABLE 12.—TENSION OF AQUEOUS VAPOR.

Temperature.	Pressure in millimeters.	Temperature.	Pressure in millimeters.
0°.0	4.5687	30°.0	31.5096
5°.0	6.5067	35°.0	41.827
10°.0	9.1398	40°.0	54.906
15°.0	12.6739	45°.0	71.391
20°.0	17.3632	50°.0	91.982
25°.0	23.5174		

It will be seen that the vapor pressure increases very regularly and rather markedly with rise in temperature. At the temperature of 0° C. the pressure is 4.5687 millimeters, while at 50° C. it is 91.982 millimeters. From these figures it can be easily conceived why the volume of air expelled from the moist soils, and the pressure exerted by the air of the same soils, do not follow the laws of Charles, but instead, they increase differently at the various temperatures, and that the actual values are far greater than the theoretical. To obtain, therefore, the real increase in volume and pressure of the air alone, containing no moisture, the increase in volume and pressure due to the aqueous vapor must be deducted from the foregoing experimental data. This can be done by the use of suitable formulae but it would be of no practical value because the data then would not show the complete influence of temperature upon soil ventilation. The expansion or pressure of this aqueous vapor is dependent upon the temperature and upon the nature of the liquid, but it is not affected by the pressure of other gases nor by the amount of the liquid present. If a closed space, such as the tube here used is filled with a mixture of gases, each gas will exert a definite pressure which is the same whether it exists alone in the space or whether other gases are present. The total pressure of the gas mixture is the sum of the partial pressure of the various gases. The partial pressure of the aqueous vapor can be determined by the formula already given, provided the gas is saturated. In the moist soil the air was saturated, but in the dry soils it was not, and some irregularities observed in the latter soils, are attributed to this fact.

As already stated it has long been known that absoption of gases by solids decreases with temperature. This fact was verified in the present investigation. In order to ascertain to what extent absorption influenced the foregoing abnormal results, on soil aeration, a series of experiments was conducted upon the subject. The problem was investigated by filling the usual tube with air dry soil and drying the latter in an oven for several hours at a temperature of 105° C. By holding the tube horizontally the solid rubber stopper and the rubber stopper which contained the bent tube, were inserted at the opposite ends. To the bent tube was attached also a tube containing $CaCl_2$. As the soil cooled it drew air through the $CaCl_2$, the latter absorbed the water vapor and thus dried the air as it entered the soil tube. The soil was cooled to 0° C. and allowed to remain at that temperature for a few hours to absorb gas and come to an equilibrium. The temperature was then raised to different degrees and the gas expelled measured in the usual manner. The quantity of gas given off was taken as a measure of the amount that would be absorbed at the same temperature since expulsion is the reciprocal of absorption. Attention must be called here, however, to the fact that the porosity of the material comes into play and consequently not all of the gas given off or taken up at the various temperatures, is due to absorption. The soils employed were the same as those in the preceding series of experiments. The results obtained are detailed herewith.

TABLE 13.—EFFECT OF TEMPERATURE ON ABSORPTION OF GASES.

Soil.	Dry wt. of soils.	Capacity of tube.	0-10°C. c. c.	10-20°C. c. c.	20-30°C. c. c.	30-40°C. c. c.	40-50°C. c. c.	Total c. c.
Quartz sand..........	202.5	152	3.3	2.8	2.8	2.8	2.5	14.2
Sandy loam...........	221.6	152	3.9	3.6	3.0	3.0	2.6	16.1
Clyde silt loam........	164.5	152	5.0	4.3	4.2	4.0	3.6	21.1
Clay.................	182.5	152	4.8	4.4	4.2	4.1	3.8	20.30
Peat.................	92.0	152	6.1	5.4	5.0	4.9	4.5	25.9

It will be seen from the above table that the amount of air given off (or absorbed), decreases regularly and gradually with temperature. It will also be observed that the total quantity is greatest in peat and decreases with Clyde silt loam, clay, sandy loam and quartz in order respectively.

From these results it is evident that absorption of gases by dry soils influences the æration of soils principally at the lower temperatures and that at the higher temperature it is the aqueous vapor which plays the most important and greatest role.

It should be mentioned, however, in passing that a certain amount of the gases expelled from moist soil with the elevation of temperature is due also to that absorbed by the soil water. How much of the total volume owes its origin to this source it cannot be stated definitely as no experimental work was performed on the subject, but probably it is comparatively very small.

Thus we see that temperature has a tremendous influence upon soil aeration and in a manner not heretofore altogether realized. It is true that the diurnal temperature amplitudes are not very appreciable below six inches, but above this depth, which constitutes that layer of soil most tilled, they are very large, and especially in certain regions of the world. Field experiments on soil temperature at this Station, which have been running for four years, show that the diurnal fluctuation in temperature in the different types of bare soil, is sometimes as high as 25° C. for the first inch depth, 15° for the second, 13° for the third, 10° for the fourth, 8° for the fifth, and 6° for the sixth, making an average of about 13° C. for the upper six inches. As a rule these fluctuations are larger for the sandy soils and smaller for the muck and peat and still smaller in cropped soils. During the warm part of the year there occurs very often excessive hot and cold days only a short distance apart. The difference between the maximum soil temperature of the excessively hot day and the minimum soil temperature of the excessively cold day sometimes amounts to 40° C. at the upper first inch of soil. On the other hand, it must also be remembered that the soil temperature undergoes great changes between summer and winter and the influence of temperature on soil aeration must be considered from this standpoint also. Hence, the temperature ranges employed in this investigation are within the limits of the diurnal and seasonal changes that actually occur in the soil.

At this point the reader may appear to be noticing certain discrepancies in the conclusions of the present research in comparison with those on the "Movement of Moisture from Moist and Warm Column of Soil to Dry and Cold Column of Soil with an Air Space between the two Columns." In this latter research it was concluded that the amount of water moved through vapor, from a point of high to a point of low temperature, and the amount of water lost from the soil through diffusion of water vapor, are practically negligible. In the present research, it has been seen that temperature causes the expulsion of enormous amounts of gas from the soil, and that this abnormal increase in volume of gas expelled is due to aqueous vapor. The reader may now ask, How are these facts reconciled, If rise of temperature causes the expulsion of air from the soil which contains moisture, then the amount of water lost from the soil through vapor alone must be very large. The answer to these questions will be found in the following table which contains the amount of water vapor required to saturate a given quantity of air at different temperatures. The amount of water vapor which saturates a given quantity of air is usually expressed in grains per cubic foot or grams per cubic meter, or it may be expressed in terms of the pressure which it exerts in millimeters or inches.

TABLE 14.—AMOUNT OF WATER VAPOR REQUIRED TO SATURATE A GIVEN QUANTITY OF AIR AT DIFFERENT TEMPERATURES.

Temperature degrees F.	Vapor pressure, inches.	Amount of water vapor in grains per cu. ft.	Temperature degrees C.	Vapor pressure, m. m.	Amount of water vapor in grains per cu. m.
			0	4.57	4.87
			10	9.14	9.36
			20	17.36	17.15
30	0.166	1.97	30	31.51	30.08
40	0.246	2.86	40	54.87	50.67
50	0.360	4.09			
60	0.517	5.76			
70	0.732	7.99			
80	1.022	10.95			
90	1.408	14.81			
100	1.916	19.79			

Considering the figures of the Centigrade scale it will be seen that the amount of water contained in a cubic meter (1000 liters) of saturated air at 20° C. is only 17.15 grams. That means that if 1000 liters of saturated air are expelled from the soil at the temperature of 20° C. only 17.15 grams of water will be lost from the soil. In table 10, it is shown that by raising the temperature of one-half cubic foot of soil from 0° to 50° C. only about two liters of air will be expelled from the mineral soils and about three liters from the peat. On the other hand, the air expelled from the soil as the temperature rises, cannot be said that it is always saturated. Hence, the amount of water that may be lost from the soil through expulsion of soil air incident to soil ventilation, is insignificant.

Before closing this section, one more point should be considered;

namely, the effect of temperature upon the atmospheric pressure, and its influence in turn upon the aeration of soils.

The diurnal variation of the atmospheric pressure may be classified thus: the chief maximum usually occurs at about 10 in the morning, the chief minimum at 4 in the afternoon, a secondary maximum at 10 in the evening, and a secondary minimum at 4 in the morning. The pressure is thus subject to double oscillation in the course of a day. The amplitude or amount of daily variation is always small, never amounting to more than 0.2 of an inch, and in many places being often less than a tenth of this.

Now, temperature undoubtedly plays a large part in causing this diurnal variation but the exact way in which it operates to produce the result cannot be satisfactorily stated. Theoretically, however, the maximum would be expected at the time of least temperature, that is, at about sunrise, and the minimum at the highest temperature, that is, from 1 to about 3 o'clock in the afternoon. At these respective periods the surface soil also attains its maximum and minimum temperature. At these maximum and minimum temperatures there occurs the greatest amount of gas exhaled or inhaled. Hence, atmospheric pressure, as influenced by temperature, tends to aid in the ventilation of soil, but in a very small degree, if any, since its diurnal variation is so insignificant.

SUMMARY.

In this bulletin there are presented the results of an investigation upon the influence of temperature on certain physical processes in the soil, such as the capillary movement and retention of moisture, gravitational flow of water, thermo-osmose, gas flow, aeration of soils, etc. It was pointed out at the outset that the influence of temperature upon these physical processes in the soil lacked experimental study and consequently our knowledge consisted almost entirely from *a priori* deductions from the physical laws of surface tension of liquids, viscosity of liquids and gases, and expansion of gases, as affected by temperature. The general problem was subjected to an experimental study and the results obtained may be summarized as follows:

The investigation upon the effect of temperature on the movement of water vapor and capillary moisture in soils shows that:

(1) When one-half of a column of soil of uniform moisture content is maintained at 20° and 40° C. and the other half at 0° C. for eight hours, the percentage of water moved from the warm to the cold soil increases in all the different types of soil with rise in moisture content until a certain water content is reached and then it decreases with further increase in moisture content. The results then plot into a parabola. The percent of moisture at which the maximum thermal translocation of water occurs is different for the various classes of soil, but the percentage of the maximum thermal translocation of water is about the same for all classes of soil for any one of the temperature amplitudes. The percentage of moisture at which this maximum thermal translocation occurs is designated as *thermal critical moisture content.*

These results are contrary to what might be expected from the laws of surface tension and viscosity. They have led to the conclusion that the capillary movement of water in moist soils is not controlled entirely by the curvature of the capillary films, as is generally believed, but also by the unsatisfied attractive forces of the soil for water.

(2) When a moist column of soil is kept at 20° and 40° C. and a dry column of soil at 0° C. for eight hours, and the two columns are separated by an air space, the percentage of moisture distilled over from the moist and warm column to the dry and cold column of soil is very insignificant for both amplitudes of temperature, and about the same for all moisture contents.

These results lead to the conclusion (a) that the amount of water lost from the soil by water vapor is very small, (b) that there is no rising of vapor during the night from the warmer soil below to the cold soil above, and (c) that the source of water of the dew is not derived from the soil vapor, as is commonly believed.

(3) When a moist column of soil is in contact with a dry column of soil and the former is kept at 20° and 40° C. and the latter at 0° C. for eight hours, the amount of moisture moved from the moist and warm soil to the dry and cold soil increases with temperature and with moisture content. But when the moist column of soil is maintained at 0° C. and the dry column of soil at 20° and 40° C. for the same number of hours, there is very little, if any, movement of water from the former to the latter.

These results have led to the conclusion that temperature has a very marked influence on the conservation of moisture by mulches.

(4) No thermo-osmotic phenomena were observed in soils.

(5) The research on the effect of temperature on the rate of percolation of water in soils shows that in the case of sandy loam, silt loam, clay loam, clay and muck the rate of flow increases with rise in temperature up to about 30° C. and then decreases with further rise in temperature. In the case of sand, however, the rate of flow increases with a constantly rising of temperature. In the former soils the results are explained under the hypothesis that the colloidal material present swells with increase in temperature and tends to close the channels through which the water flowed.

(6) The water holding capacity of soils decreased with rise in temperature, but this decrease is not due entirely to the diminished surface tension of the soil water but also to other factors.

(7) The rate of flow of air through soils decreases with rise in temperature. This dimunition is not entirely due to the increased viscosity of the gases, but in addition to some changes which the temperature produces in the soil.

(8) Temperature has a tremendous influence upon the aeration of soils. This influence is not due merely to the expansion of gases of the soil, as is commonly believed, but also to the absorption of gases by the soil at different temperatures, and to the aqueous vapor.

A SIMPLIFIED APPARATUS FOR MEASURING THE CONDUCTIVITY OF ELECTROLYTES.

Technical Bulletin No. 23.

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FOREWORD.

This bulletin entitled "A Simplified Apparatus for Measuring the Conductivity of Electrolytes" is mainly technical physics and discusses the means of improving and making more accurate the methods of determining the conductivity of solutions. The bearing that this has on certain plant physiological investigations comes from the fact that in studying the question of nutrition, in particular, of the absorption of water and mineral nutrients, it is essential to have very accurate means of determining the salt content of the solutions used before, during, and at the close of experiments.

When Dr. Hibbard began experiments, the known methods were found to be either comparatively crude, or exceedingly complicated, but with the help of Professor Chapman he has simplified the apparatus very greatly while at the same time he has improved its accuracy to an equal degree.

I feel that this bulletin will be of value to workers in similar lines elsewhere as well as to physicists and chemists in general who demand very accurate means of determining in the electrical way the salt content of solutions.

ERNST A. BESSEY.

1. INTRODUCTION.

The most important problem in plant physiology is doubtless the general one of nutrition. Under this heading there are numerous subsidiary problems which have partially or entirely evaded explanation. Until recent years physiologists have had to depend upon the known facts of physics and chemistry, but now the closely allied subject of physical chemistry, which has been making rapid strides in the past ten or fifteen years, reveals many principles which offer invaluable aid. It is true that many subjects in this comparatively new science do not touch directly the activities of plants, but there are others which concern the student of plant physiology very closely. The newer knowledge of *solutions* is of fundamental importance. In no condition outside and inside the plant does matter play a more important physiological role than in a state of solution in water. Some soil solutions are dilute in respect to the minerals present in them and no doubt the solutes undergo a more or less complete dissociation, the former being true at infinite dilution. These solutes no longer exist as definite chemical compounds but are split up into part-molecules or ions each of which carries a charge of electricity and thereafter whatever properties the solutions may possess are due to the properties of these ions and the undissociated molecules when present.

The plasma membrane surrounding the living portion of each cell prevents the entrance of any substance not in solution. Thus the knowledge of the behavior of solutions is of greatest value for a proper interpretation of the absorption of electrolytes from the soil. Recent data obtained from conductivity measurements lend support to the theory that the solutes in the soil solution enter the plant in ionic form. The general problem of permeability has received added impetus through the application of certain principles of physical chemistry. To the plasma membrane has been assigned the property of selective permeability and it is here also probable that we are concerned with ion permeability. Perhaps the most accurate and at any rate the simplest method for determining the changes in permeability, since doubt has been cast on the plasmolytic method, is the one of electrical conductivity. In the hands of Prof. W. J. V. Osterhout (19-31) the method has brought out many interesting facts. Permeability is altered by a variety of substances and conditions, and the plasma membrane is proteid rather than lipoidal in nature. The cell must be considered as a dynamic entity passing through various transformations and existing in a medium that is continually changing in a chemical and in a physical way. These complex conditions must give rise to new relations between the membrane, the various parts of the cell, and its environment. Consequently the permeability of the membrane will be constantly changing. It is better to accept the view of selective permeability, though we cannot explain it in its intricate phases, than to assume that the membrane is quite impermeable to many of the solutes and that when these do penetrate, the membrane must "leak."

The concentration of the cell sap is rarely or never the same as that of the solution outside the plant, or in the conducting tissues of the plant. There is therefore established a movement of water into the cell, and a production of a hydrostatic pressure equivalent to the osmotic pressure of the dissolved substances. This pressure pushes the protoplasm outward and keeps the membrane tense and rigid. Osmotic pressure therefore has a definite function. It maintains and regulates turgor. A knowledge of solutions is necessary to a proper understanding of this phenomenon.

Much information has been collected to show that the molecules of solutes obey the well known laws of gases. A substance in solution in water acts essentially as a gas. These particles are not so free to move as in the gaseous state because of the friction between them and the molecules of water and thus great pressures are necessary to move them through the water or to separate them. This applicability of the laws of gases to solutes has made evident the proper basis of comparison between solutions of different compounds. So, now, solutions for comparison are equimolecular ones, and are not made on the percentage basis. We must take this fact into consideration in studying the influence of different salt solutions or nutrient solutions on the physiology of plants. The problems of balanced solution and antagonistic action have depended almost entirely for their explanation on a knowledge of physical chemistry.

Conductivity measurements have helped immensely in the study of the influence of concentration on the absorption and excretion of solutes by the roots of plants while growing in dilute culture solutions. There is a certain concentration for each salt or mixture of salts at which the roots excrete and absorb electrolytes at the same rate. At certain concentrations on either side, one function overbalances the other. Thus a knowledge of the culture concentration which is best fitted for the development of the plant can be obtained through conductivity studies. The conductivity method is the easiest and most accurate, since the resistance to the passage of an electric current is a function of the number of ions present in the solution, and the number of ions is in turn the index of the concentration. This is true only in dilute solutions where complete dissociation has taken place.

The presence of colloids, that are of constant occurrence in the soil, gives rise, in the soil solution, to a phenomenon called adsorption. Altho a subject containing little that is definitely known, it is nevertheless of much importance. A more thorough study from the vantage point of our present knowledge of physical chemistry should clear up much of the haze that envelops this subject. Physical adsorption as it is often called to distinguish it from absorption and chemical combination is defined as a concentration of one component on the interface between two phases. In dilute solution the solute is very likely adsorbed in ionic condition and if the assumption is true, that the adsorbed ions are then inoperative, the conductivity of the solution would be a measure of the amount of adsorption. In complex systems special conditions would arise and introduce errors which would have to be rectified in some way, in order to make this method applicable.

Certain physiologists, pathologists, biochemists, and others have made use of conductivity methods, but, because of inaccuracies and difficulties attendant upon a measurement, comparatively little work except of a general nature has been done. The names of Roth (33), Bugarzky and Tangle (3), Sjöquist (37), Stewart (35), Woefel (45), Oker-Blom (18) and McClendon (16) stand out prominently. Their work was mostly concerned with the blood of animals and the eggs of shell fish. Osterhout (19-31), True and Bartlett (39-40), Dixon and Atkins (6-7), Stiles and Jörgensen (36), Bouyoucos (2), and others have entered the field from the botanical side. Bayliss has collected data on the hydrolysis of various proteids by the action of trypsin. He measured the increase in conductivity brought about by the reaction of the enzyme. Ziegel (46), van Suchtelen and Itano (41) have described electro-titrametric methods for determining the end point in reaction. Küster and Grüters (15) used the conductivity method as an indicator of neutrality in the titration of weak acids by strong bases. They also used the same method to determine the acidity of colored liquids where the color change of the indicator would be masked. Hall and Bell (8), and Patten and Robinson (32) working independently of each other applied the method of conductance to the determination of the neutrality of ammonium citrate solution. The work of Whitney and Means (44) and Davis and Bryan (4a) was along the line of developing a simple and efficient Wheatstone bridge that could be used in the field. This résumé of the literature does not claim to be exhaustive, the only purpose being to indicate the lines of study and direction of investigation.

Since the problems, which in all probability will lend themselves to solution through the aid of conductivity measurements, are numerous, and since so few have considered the results commensurate with the time, labor and patience in making a measurement, it is evident that any improvement of the old method will tend to enhance its value and lead the way to a clearer understanding of some of the little known biological problems. The old method, as has been admitted, is not free from many sources of error. It is not an easy matter to make a measurement and more time than ought to be necessary is consumed in making it. Besides the nerves of the operator are constantly under strain. With the changes suggested in the following pages, one is now able to obtain a high degree of precision with greater rapidity and much less strain on the nerves. The correct bridge setting is determined by the aid of the eye instead of the ear, a change which will no doubt greatly commend the method.

In the spring of 1913, by permission of the Director of the Experiment Station, a preliminary paper by the senior author (10) was published in the 15th report of the Michigan Academy of Science. Shortly before this, and while we were still working on the problems, there appeared in the February number of the Journal of the American Chemical Society a paper on "An Improved Apparatus for Measuring the Conductivity of Electrolytes," by E. W. Washburn and J. E. Bell (42). The method outlined in this paper was based upon three important changes in the customary apparatus. Working independently of these investigators, we made our changes along the same general line. However, our studies led us to introduce a still further change in the apparatus. The two systems differ radically in the type of detector used. We used the alternating current galvanometer, while Washburn and Bell still made use of the telephone, which they have, however, greatly improved.

The conductivity of a solution of any electrolyte is simply the reciprocal of its resistivity. The resistivity of that solution is usually measured by balancing it against a known standard resistance. The apparatus used is the well known Wheatstone Bridge. This is a network of six conductors represented in one of the following three forms all of which are equivalent. See Fig. 1. Like letters designate the same conductors and the same points of connections in all. In the text books of physical chemistry the sketches are more diagramatic usually taking the form represented in Fig. 2. The parts referring to the six conductors are

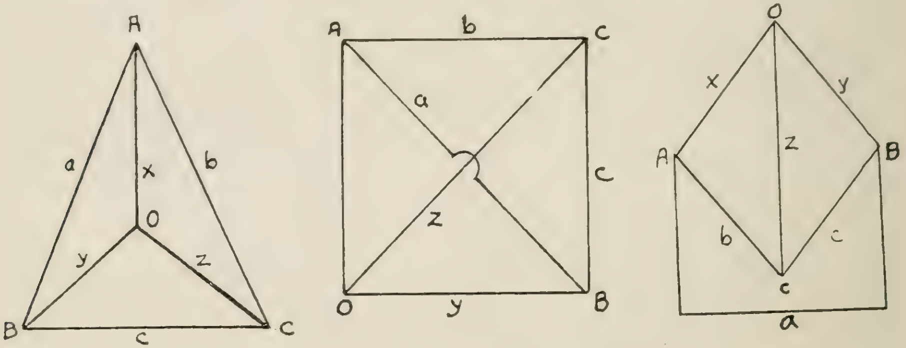

Fig. 1.
Conventional diagrams of the six conductors in a Wheatstone Bridge Network.

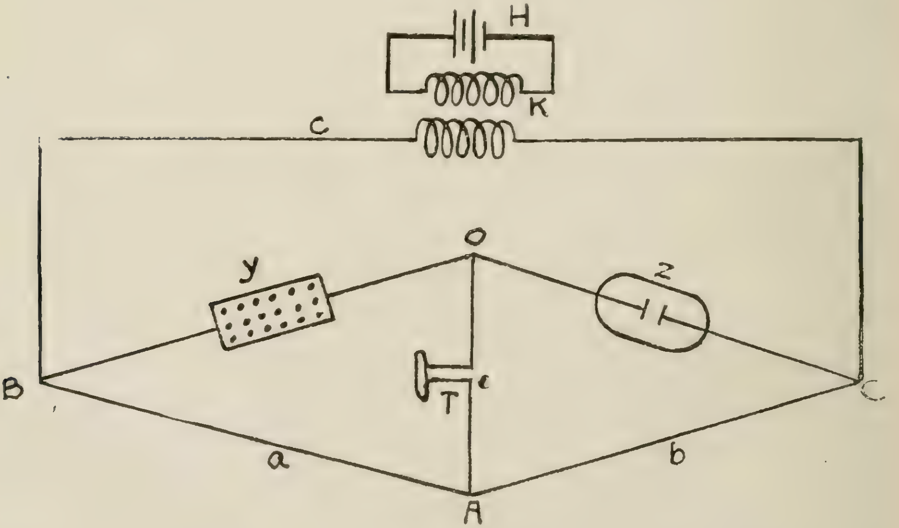

Fig. 2.
Conventional drawing of the parts of the Kohlrausch Setup. T, telephone; Z, electrolytic cell; Y, resistance; K, induction coil.

lettered exactly as in Fig. 1. The letter H represents the battery which actuates the induction coil K. The known resistance or set of resistance coils is Y, the unknown resistance or the solution whose resistance is desired is Z. T is the telephone. At this place it is not necessary to go further into the theory of conductance measurements but merely to call attention to the fact that this network illustrates the "Null" method in which the quantity being measured is balanced against some other quantity and the point of equilibrum determined by means of a telephone. It is less rapid than the deflection method but on the other hand is much more accurate and there is less necessity for applying corrections. "Null" methods are generally to be preferred for all precision work.

The Wheatstone Bridge network described below is the outcome of a systematic study of the various sources of error in the ordinary method. We were led to such a study because of all the known methods for determining the resistance of electrolytes none proved suitable for the particular problem then under investigation. Not only were there certain errors that could and should be eliminated, but the method we thought could also be simplified and made rapid and easy. It has been assumed, in the case of dilute nutrient cultures that the external errors due to the nature of the experiment are greater than the errors due to the apparatus. If this is true it is hardly advisable to improve the apparatus. However, the methods of control can be greatly improved so that a corresponding improvement in the apparatus is welcomed. It is obviously better to control all the errors possible, whether of the apparatus or experimental technique, than to be satisfied to "let well enough alone." In addition to its value to the biologist this method can be used by the most exacting physical chemist. It has a precision ten times that of the Kohlrausch method, and the measurements can be made with ease and rapidity.

2. CONSIDERATION OF THE SOURCES OF ERROR.

SOURCE OF CURRENT.

All those who have had any experience with the usual method of determining the conductance of electrolytes will agree that of all the parts of the apparatus the induction coil gives the most trouble. It is continually getting out of adjustment. Sometimes this happens while a measurement is being made. Perhaps one of the larger more expensive coils is less apt to get out of order. These, however, are not as efficient as the small cheap ones because in the latter the current that passes at each pulse is small, and consequently, error from polarization is negligible. Again, in the small cheap induction coils the vibration of the "hammer" is rapid and the tone, therefore, is high-pitched and more readily audible in the telephone. A tone similar to the hum of a gnat is the most desirable.

There is a more serious trouble in the use of the induction coil than that mentioned above and for this reason it should be abandoned. The

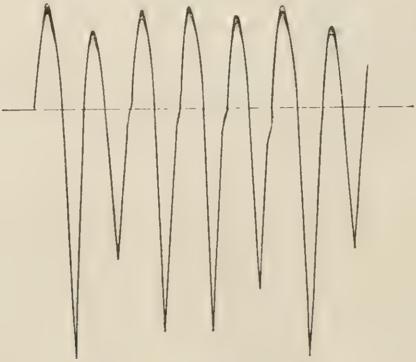

Fig. 3.

Curve from an oscillogram of an induction coil current. After E. W. Washburn. From page 10, catalogue 48, 1915, Leeds & Northrup Co.

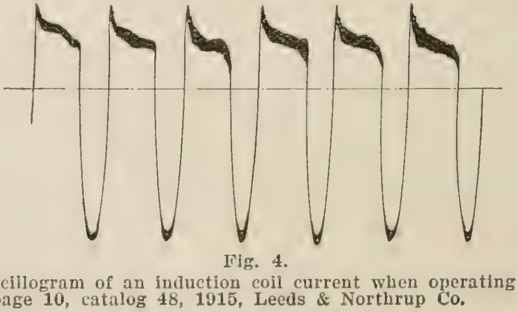

Fig. 4.

Curve from an oscillogram of an induction coil current when operating well. After E. W. Washburn. From page 10, catalog 48, 1915, Leeds & Northrup Co.

coil does not give a current whose integral value is zero. In other words, the current is not alternating; merely pulsating and having a unidirectional component. This condition of affairs gives rise to polarization because of a counter e. m. f. and consequently a false reading. Altho we had assumed that such errors existed, and our assumption appeared justified, they had not been experimentally verified. Dr. Washburn, however, has recently shown by means of curves obtained from oscillograms, that these errors were present. Fig. 3 is a curve taken from an oscillogram of an induction coil current. It shows clearly that the current is not alternating. Fig. 4 represents the e. m. f. wave when the induction coil is operating well. By plotting the areas of the positive and negative loops with a suitable measuring device it will be seen that they are not equal, therefore the e. m. f. in one direction is greater than in the other and we have a unidirectional current. This same conclusion was reached by Dr. Washburn from another experiment. When the current from the secondary of an induction coil is passed through a silver coulometer a deposition of silver takes place, hence there is a polarization at the electrode and the current is unidirectional. The introduction of another electrolytic cell in the adjacent bridge arm has been suggested as a means of balancing out the polarization effect. This unfortunately does not correct the trouble because the cell itself is a source of error especially on account of the temperature uncertainties.

When used with the telephone the induction coil is not free from over tones and the frequency is not always constant for a sufficient length of time. If it should happen to maintain a constancy for a sufficient time it is apt to change in tone unexpectedly. Thus an improvement in the telephone, which recent work in wireless telegraphy has made possible would be of no advantage. Therefore, for precise work, the induction coil is not satisfactory.

The Siemens and Halske high frequency generator, in connection with the telephone, has been used, but this only produces an approximate sine wave even when operated on a current of constant potential. To protect it from varying loads and to detect such variations, quite an amount of auxiliary apparatus is necessary. A 110 volt generator to drive the machine; two mica condensers to vary the capacity of the circuit and distribute it symmetrically in respect to the generator; a device for detecting the frequency and to indicate when corrections should be made; two rheostats, one to control the speed of the motor and the other to vary the exciting current employed during a conductance measurement; and a hot wire ammeter to indicate the condition of the current, constitute the necessary apparatus. Such an array of apparatus will need constant care and watching to keep in good working order. It cannot be assembled in one place. The operation of certain parts interferes with the proper working of others. The generator because of the noise produced by the rapidly revolving toothed wheel must be put away in a room some distance from that in which the measurements are being made. The operator must be in a quiet place in order to determine the minimum tone through the telephone. This auxiliary apparatus costs in the neighborhood of $300 and if it constituted all that was necessary for determining a conductance measurement, an objection might not be forthcoming. This is, however, only a small part, and simply arranges for a current of constant potential to the bridge. Probably the best source of constant potential is the Vreeland Oscillator recently put on the market. It is the easiest to keep in running order and most convenient to handle. No condensers, frequency meters, hot wire ammeters, etc., are necessary. It is noiseless and therefore can be kept near the operator if need be. In addition, it has the great advantage of producing a pure sine wave. Even in the cheaper form, the price of this instrument is $225, and is obviously too much to lay out on one part of a Wheatstone Bridge network.

All these instruments give a frequency of 1,000 cycles per second. The use of a frequency of 60 cycles in conductance measurements of liquids will, in all probability, be viewed with suspicion, and we might also add that that was our earlier attitude. It is asserted that, working with such low frequencies, the results are liable to error from polarization. However, after the continued use of this frequency, in connection with a sensitive indicator and the control of certain other necessary conditions, over a period of two years, we believe that the difficulties assumed are more apparent than real. Let us consider the theory for a moment. We can assume that, for a very *small* current passing for a short time, the e. m. f. of polarization is proportional to the quantity of electricity which has passed through the cell. When measured by a balanced Wheatstone Bridge the resistance will increase with the time that the current is kept on and will always be higher than the true resistance. For this reason the use of the Wheatstone Bridge with *direct current* is not suited to the determination of the resistance of solutions of electrolytes. If, on the other hand, one uses alternating current and a sensitive detector the principle of the Wheatstone Bridge can be used with accuracy. This is so, quoting from Dr. Northrup (17), "because the e. m. f. of polarization, produced by the current in one direction, and which would lead to a balancing of the bridge giving too high a value of the resistance, will, upon the reversal of the current, either be neutralized or, if not neutralized, will lead to a balancing of the bridge giving too low a value of the resistance. Thus the setting actually obtained for a balance is the same whether polarization is neutralized or not, as would be required were there no polarization." A statement of this kind from such an authority should cause us to reconsider our ideas of the possible error from polarization.

It is a well known fact that the amount of hydrogen separated per square centimeter at the electrode is directly proportional to the current passing. By regulating the current so as to make it small, the amount of substance separated at the electrodes, or in other words the polarization can be made negligible. When the alternating current changes rapidly such as it will at a frequency of a thousand we are told that polarization is not likely to take place. There is not sufficient time for hydrogen to separate out before the phase is changed. At 60 cycles where more time elapses before the change to the other phase takes place it has been assumed that the hydrogen might possibly have time to diffuse into the solution and thus change the concentration. We are told that only under special conditions will the error from polarization be rendered small enough to permit measurements at 60 cycles per second. These statements above might lead one to believe that we have taken a lot for granted and accepted without reserve a lot of assumptions. In all our experiments we have not had any trouble from polarization which could not be eliminated. Because of the nature of the indicator we use it is not necessary to pass the current through the network or system for more than a second at a time and thus the chance for error from polarization is very slight if any. In addition, if one platinizes the electrodes well and then selects the proper form of conductivity cell for solutions of high or low resistance, as the case may be, there is little danger of error from polarization.

INDICATOR OR DETECTOR.

There are a number of instruments that have been used to determine when the solution whose resistance is desired, is balanced against the known resistance in a Wheatstone Bridge network. The one that has been used more than any other is the telephone. Recent advances in wireless telegraphy have had much to do with the improvement of the telephone. It is claimed by some to be the best detector, and because of the improvements made we have the probable reason for its continued use. For precise work the telephone with all its improvements must be used in an absolutely quiet room. An improvised telephone booth should be provided. The operator must also give his undivided attention to the work of listening. The strain on the nerves is severe. It is exceedingly hard even under these conditions to detect a "perfect minimum" or a point at which no sound is heard. To determine the exact point where a constant but gradually decreasing sound stops, is difficult. One often imagines he hears a sound when in reality he does not. A continual hum in the head often follows the operator to his recreation for some time after he has left the laboratory. Recently the senior author was told that this trouble in determining the "perfect minimum" was obviated by a certain attachment on the telephone which caused a series of interrupted noises. When these staccato sounds were not heard the balance had been reached. Up to the present time he has been unable to find any article describing the modified telephone but it appears very possible that such a change could be made. An improvement of this sort would be welcomed.

The telephone at its best is one that is "tuned" to the frequency of the exciting current and this is usually a thousand cycles per second. Even the best telephone, however, is not the best detector. There is a residual tone that cannot be eliminated and which is always present to interfere with the detection of the tone of the machine. The tones most evident in an alternating current are the upper partials, especially the upper third. One can modify the diaphragm of the telephone to eliminate this, but as one corrects one error, one falls into another. This correction would produce a sharp tuning curve and require too close a control of the frequency which in turn is difficult to maintain when there is any variation in the operating current. An extra equipment noted above has to be supplied. With the telephone as the detector a fairly close adherence to the frequency is necessary. A deviation of 100 cycles per second halves the sensitivity. The difficulties attending the use of the telephone outlined above led us to select an instrument which would not necessitate the use of the ear. Our best results were obtained with the Alternating Current Galvanometer with a mirror and scale. This is more satisfactory than the telephone in many respects.

Probably the two greatest factors which influence the sensitivity of any resistance measuring device are the constant of the detector and the magnitude of the current. In the latter case there are certain limitations which are dependent on the capacity and heating effects in the resistances, and in the former the limitations are only those that can be overcome. If it were not necessary, for example, to load a galvanometer system with a mirror for the purpose of reading a deflection, and if again the moment of inertia of the movable coils were as small as possible and if still further the coils were wound non-inductively and for the annulment of capacity, then the galvanometer would have a large figure of merit. Progress in galvanometer construction is being rapidly made, and it only rests with the future to produce an extremly sensitive apparatus. The use of a galvanometer of the dynamometer type as a detector for liquid resistances was suggested more than fifteen years ago by the late professor Rowland (34) of Johns Hopkins University. It is surprising to note that apparently little attention has been given to this suggestion. The following quotation is taken from his Physical Papers, page 294:

"I also give a few methods of resistance measurement more accurate than usually given by means of the telephones or electrodynamometers as usually used and especially suitable for resistances of electrolytic liquids"—"I have introduced here many new methods, depending upon adjusting two currents to a phase-difference of 90° which I believe to be a new principle. This I do by passing one current through the fixed coil and the other through the suspended coil of an electrodynamometer. By this means a heavy current can be passed through the fixed coils and a minute current through the movable coil, thus multiplying the sensitiveness possibly a thousand times over the zero current method." "Using non-inductive resistances, methods 10 and 14 are especially good and I have no doubt, will be of great value for liquid resistances. The liquid resistances must, however, be properly designed to avoid polarization errors." "Altogether the results of experiment justify me in claiming that these methods will take a prominent place in electrical measurements especially where fluid resistances, * * * are to be measured. The new method of measuring liquid resistances with alternating currents allows a tube of quite pure water a meter long and 6 mm. in diameter having a resistance of 10,000,000 ohms to be determined to one in a thousand or even one in ten thousand. The current passing through the water is very small, being at least 500 times less than that required when the bridge is used in the ordinary way. Hence polarization scarcely enters at all." We reproduce two of his figures below (Fig. 5). In these two methods the concentric circles are the coils of the electrodynamometer. Either one is the fixed coil and the other is the hanging coil. Oblong figures are the inductances and when near each other are mutual inductances. A pair of cross lines is a condenser. This quotation is given in full because of its bearing on the present work and to aid in counteracting the general notion that the telephone is good enough.

There have been several objections to the use of the dynamometer but none of these appear to have any foundation. It has been claimed that the most serious objection arises from the fact that the two currents might sometimes be in quadrature. In this case, though the bridge is unbalanced and a current is passing through the coils, there will be no deflection of the galvanometer scale. Should such a possible condition arise it could be eliminated by the introduction of a condenser to produce a "lead" in the current. In all our experiments we have never experienced this trouble and yet if it should arise we have a suitable means of controlling it.

It has also been objected that the necessarily strong current in the coils to produce the greatest sensitivity would in turn produce such a load on the electrolytic solution as to exert a deleterious heating effect. This objection is not valid. Such a trouble can be obviated by introducing a variable resistance in the bridge circuit to control the amount of current to any strength desired. This heating effect is sometimes quite appreciable, and causes a very considerable error. It takes place in the more concentrated solutions. To determine the resistance of such solutions only a small amount of current is necessary. Cutting down the current does not decrease the sensitivity when working with such solutions. A paragraph from the works of Professor Rowland concerning the sensitivity of an electrodynamometer is quoted here:—"An electrodynamometer can be made to detect .0001 ampere without making the self inductance of the suspended coil more than .0007 henrys or that of the stationary coils more than .0006 henrys, the latter readily sustaining a current of 1/10 amperes without much heating." The point of balance is exact.

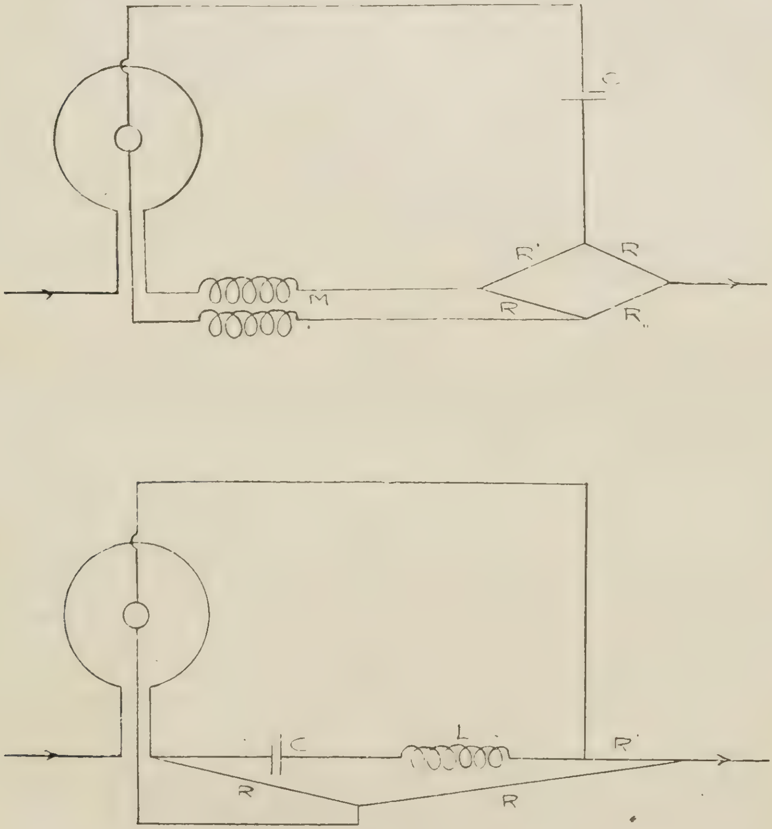

Fig. 5.

Diagram of connections when using an electrodynamometer. From Henry A. Rowland's Physical Papers, Figs. 10 and 14, page 302.

The galvanometer has at least four advantages over the telephone. 1. The direction of the deflection indicates on which side the bridge is unbalanced and the exact balance can be made easily and quickly. On the other hand in the case of the telephone the sound increases equally without distinction for a departure from the setting of the resistance in either direction from that which gives a true balance. 2. When the current is put on, the direction of "creeping," if there is any, will indicate whether there is polarization or heating. This will quickly show where and how the changes in the system are to be made. 3. It is only necessary to close the switch for less than a second at a time when finding a balance. Consequently the possible error due to heating or polarization is negligible. When using a telephone the current is on all the time until the balance is found. 4. The eye is more accurate than the ear and even if the two instruments had the same figure of merit the one that makes use of the eye is preferable. The operator is not under a nervous strain even if he desires to attain an accuracy of .001 of 1%.

The galvanometer costs more than the telephone but it is a well known fact that in general, increased sensibility in the indicating device leads to a reduction in size and cost of all the rest of the equipment required.

RESISTANCES.

The ordinary resistances and even the best grades of coils put out until recent years are not suitable when measuring the resistances of dilute solutions of electrolytes providing accurate results are desired. This is so because the coils are not free from capacity and inductance. These are the two great sources of error to be guarded against when using alternating currents. In a system like the Wheatstone Bridge every conductor has a capacity especially when it is surrounded by other conductors and this capacity can be defined as the ratio of the charge of the conductor to the potential produced by the charge. Its value is dependent on the form and dimension of the conductor and the nature of the dielectric. The electrolytic cell and the resistances act as capacities and vary with the current period. High resistance coils give the larger error. With resistance coils of 20,000 ohms or more, the power factor is large on account of the poor dielectric which the resistance contains. Consequently the capacity is large.

The general effect of capacity is to produce a "lead" in the phase and whenever the phase difference is large the currents are apt to be in quadrature and in this case though a current passes through, no deflection of the galvanometer scale is produced. Therefore correct resistance values can only be obtained by meeting the condition that the four arms of the bridge are without appreciable capacity and inductance. The new resistance coils are now wound to avoid capacity and inductance. The capacity of the electrolytic cells is eliminated by introducing a condenser of proper value. Kohlrausch (14) drew attention to this matter some time ago, but it is only in recent years that our knowledge of condensers has sufficiently advanced to develop one that is efficient. The coils in the bridge should also be wound to avoid capacity and inductance.

The effect of unbalanced capacity is to make the "balance point" less precise. The "balance point" is taken as that point where there is no deflection. This means that the unknown solution in the cup just balances the known resistance. This definition further assumes that a movement of the bridge, in either direction, as much as a tenth of a scale division should cause a deflection in the galvanometer scale. Under some conditions the range may extend a number of scale divisions before deflection occurs. Thus only an approximate value is obtained and the reading is not precise. By using a condenser this error can be corrected to a certain extent, but it is far better to avoid the use of condensers and use resistances which have no capacity.

Again capacity effects increase with the frequency and soon produce heating which will raise the true resistance value and thus introduce an error. At a frequency of a thousand cycles per second the current does not flow equally through the cross section of the conductor but is confined mainly to its outer surface. Consequently when the current is not distributed equally heating results and the resistance rises and there is a false reading.

By using alternating currents the errors from self inductance are greatly increased. With direct current self inductance only occurs at the making and breaking of the circuit. Alternating currents are not only passing forward and backward, but are rising and falling in value and such changes in a conductor will induce in it a counter e. m. f. This self-induced e. m. f. will be in such a direction as to oppose the change of current which it produced. The amount of self inductance is dependent on the rate of change in the current. Obviously alternating currents, and these at a high frequency introduce a great error. These can all be eliminated by using resistances wound non-inductively. The new Curtis resistance coils are such, and they are the only suitable ones for electrolytic measurements.

RESISTANCE CELLS.

The solutions or living plant or animal tissues to be studied, are placed in certain resistance cups or cells. The form, shape and size of both the cups and the electrodes are matters of importance. The accuracy of a measurement is dependent to a great extent upon the design of the cell. Freedom from impurities must be assured. The construction of the various parts must not be lightly considered. There are a number of factors, which make it necessary to construct resistance cells of various forms. In regard to solutions, one particular form is not suitable for concentrated and dilute solutions alike. The form of the cell is dependent upon the size and shape of the electrodes and upon the distance these are apart. In turn the nature of the solutions controls the size and shape of the electrodes and the distance they should be apart. For convenience these cells have been grouped according to the purpose they serve. 1. Resistance cups for good conducting fluids. 2. Resistance cups for poor conducting fluids. Several different forms are figured in the publication of Kohlrausch and Holborn (14) and recently new forms by Prof. Washburn are pictured in catalogue No. 48 of the Leeds & Northrup Company. The Fritz Kohler catalogue for 1909 also shows a number of forms.

The electrodes are usually circular in form and consequently the resistance desired is the resistance of a cylinder of liquid enclosed between them. This cylinder is modified greatly by either varying the distance between the electrodes or increasing the surface of the electrodes. As a general rule, it may be said that the electrodes must have a large surface and be close together when the solution to be measured is "conductivity-water" or a solution which is extremely dilute in respect to its solute content. Conversely it follows that the electrodes must be far apart and the surface small, if one wishes to measure the resistance of concentrated solutions. In the former case, conditions are such as to favor the passage of a strong current, while in the latter a weaker current is allowed to pass and a further hindrance to its passage is effected by increasing the distance through which it is required to pass.

It is necessary that the platinum be of the best quality and free from lead and calcium. Also it must be stiff enough so as not to change shape or get out of position. Otherwise the cell constant would vary and introduce a source of error. Certain modifications of the cell and its electrodes have much to do with the control of error from polarization. Platinized electrodes increase the surface enormously. Kohlrausch estimated that a coating of platinum black increased the surface a thousand times. With electrodes of such large surfaces polarization is negligible. Platinum black absorbs the gas as soon as it is separated out and it does not therefore modify the concentration of the solution. The statement has been made that it is unnecessary to platinize electrodes. From our experience with a frequency of 60 cycles per second we obtain better results with platinized electrodes than with bright electrodes. It has been argued that bright electrodes are preferable since platinized electrodes cannot be used in all cases. Platinum black acts as a catalytic agent under certain conditions and will bring about chemical reactions. A proper selection of the solution or a modification of the electrodes will obviate this difficulty. Again, on account of the spongy nature of platinum black, it is argued that it will absorb some of the electrolyte, and when the same cell is used for another solution of different concentration or character, it will cause an error in the measurement. By taking a new clean cell, or by cleaning the old one this trouble can be corrected.

Another factor in regard to the construction of resistance cells must be kept in mind. There must be the smallest amount of space possible between the lateral edge of the electrodes and the glass walls of the electrolytic cup. When working with nutrient culture solutions in different sized beakers a new form of electrolytic cells is used. This is called the "plunger" cell. The electrodes are enclosed in a cylindrical glass chamber and always maintain the same position in reference to the side walls of the chamber. The chamber is pierced at the bottom and top by three holes. When this is plunged into the liquid in the beakers the solution passes through the holes and surrounds the electrodes. When everything is at rest a measurement can be made. When measuring the resistance of living or dead tissue another form is required. This must be made mechanically rigid and allow for an arrangement whereby the tissues can be securely and firmly clamped between the electrodes. This form is one devised particularly for work with tissues and is figured in this paper.

SUMMARY.

The following conclusions can be drawn from a consideration of what has been said concerning the sources of error in the usual Wheatstone Bridge set up. The induction coil as a source of current must be abandoned. The telephone is not as sensitive as the alternating current galvanometer of the dynamometer type. The common resistance coils are not suitable for work of precision and must be replaced by the Curtis Coils which are wound to avoid inductance and capacity. The resistance cups must be selected according to certain necessary conditions. A condenser must be used across the resistance to balance out the capacity in the electrolytic cell. In the following pages we describe the apparatus we have been using and then add the results of a few tests to show the precision which this method attains.

3. THE SIMPLIFIED RESISTANCE MEASURING APPARATUS.

When working with electrical instruments, or a resistance measuring network like the Wheatstone Bridge it is a good plan, on general principles, to select the apparatus so that its various parts are in conformity. It is therefore necessary to know the various pieces and to be able to judge as to the relative value of things. It is obviously wrong to use a poor grade low resistance and a moderately sensitive detector if one desires to measure conductivity water. There are other arrangements which should be condemned, but yet are not so apparently wrong as in the above illustration. Each part should be selected and arranged to conform to certain demands in other parts. In the usual method the stationary coils and the swinging coils of the dynamometer have been connected in series. The better way and one in which the sensibility is increased nearly 1,000 times is to connect the swinging coils across the bridge and place the stationary coils in the main circuit. We believe, after working for some time with all the old and the most recent devices for measuring the conductivity of electrolytes, that we have now brought together a simplified, accurate and efficient apparatus. Fig. 6 shows the arrangement and scheme of connections for the new apparatus. Fig. 7 represents the apparatus all assembled ready for a measurement.

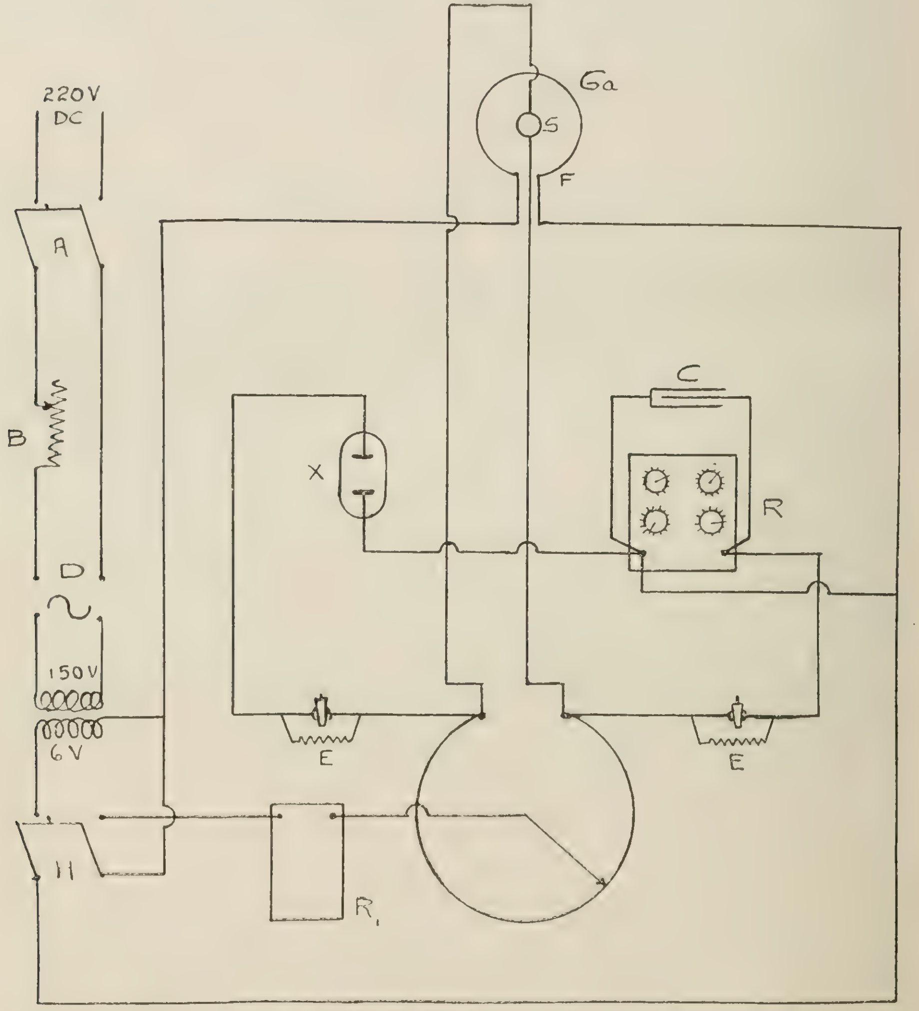

Fig. 6.
Scheme of connections of the apparatus used in this paper.

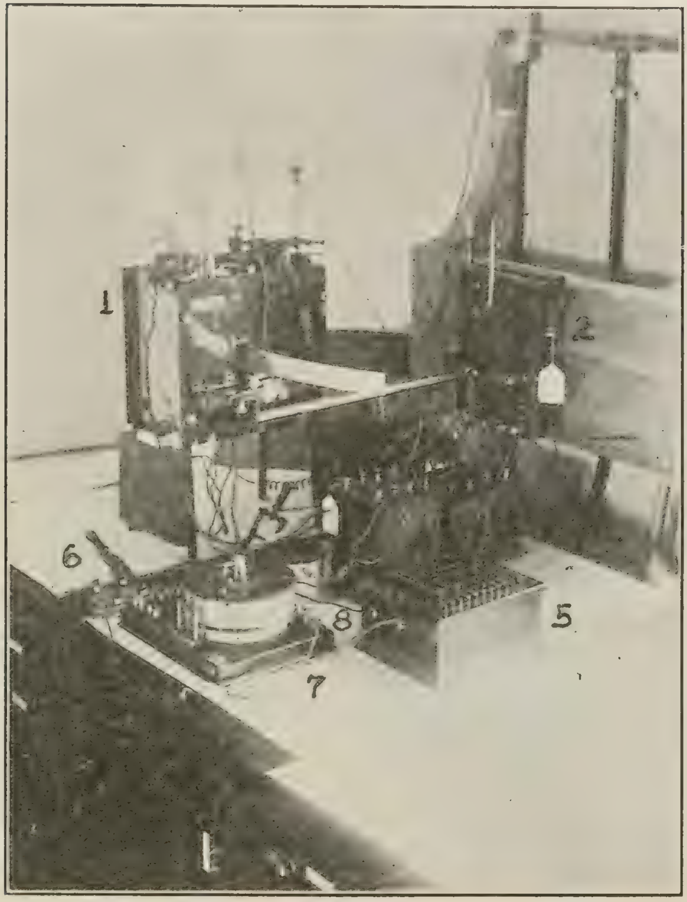

Fig. 7.
Complete Setup.
1. Bath. 2. Galvanometer. 3 and 4. Curtis Coils. 5. Decade Resistance in bridge circuit. 6. Switch controlling bridge and galvanometer circuit. 7. Bridge. 8. Condenser.

SOURCE OF CURRENT.

The source of current is a 60 cycle rotary converter. The first converter used was a large stationary type run on a constant potential of 110 volts from an Edison storage battery. The first studies were made in the electrical power laboratory of the physics department. Later work was done in the botanical laboratory and the current derived from a small portable 1/10 horse power, 60 cycle, rotary converter. (Fig. 8). This was obtained from the Holtzer Cabot Electric Company of Boston. It proved very satisfactory. A variable transformer was used in connection with this converter to cut the current down to 6 volts. This was then connected with the bridge circuit and the stationary coils of the galvanometer circuit without further change. In a previous part of this paper reasons were given to show that no errors but what could be corrected could arise from the use of this frequency. The converter and its transformer were stored away under the table and kept from the galvanometer so that the latter would not be exposed to any external electric field. Underneath and at the side of the table within easy reach of the operator a switch and starting box was placed. It was deemed advisable to use a starting box so as to avoid any injury to the rotary converter through overloading.

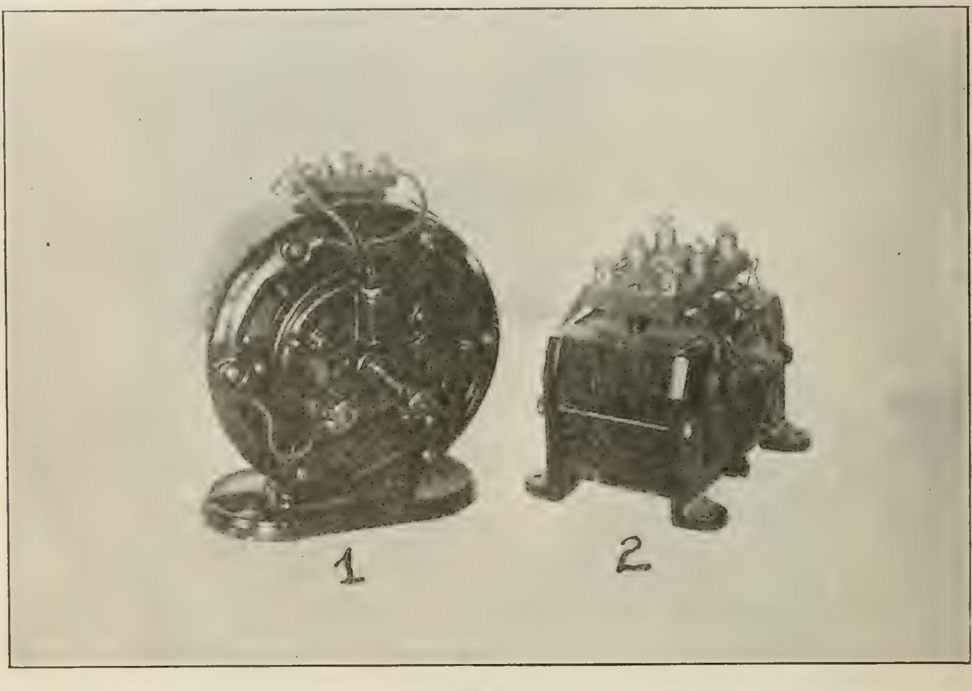

Fig. 8.
Source of alternating current. 1. Rotary converter. 2. Transformer.

DETECTOR.

The instrument used to determine when a balance had been found was an alternating current galvanometer of the electrodynamometer type, first suggested by Prof. Rowland in 1897. This galvanometer was made by the Leeds & Northrup Company and has proven very satisfactory. Fig. 9 shows the scheme of connections. The fixed coil of the galvanometer is placed in the main circuit to increase the sensibility of the apparatus. The swinging coil is connected across the bridge in the same manner as with the telephone in the Kohlrausch method. The resistance of the fixed coil is 29.8 ohms and the maximum allowable current is 1/5 of an ampere for 10 second periods. By throwing on the 6 volts from the transformer this value of the current is just reached. The resistance of the swinging coil is 21.8 ohms and the maximum allowable current is

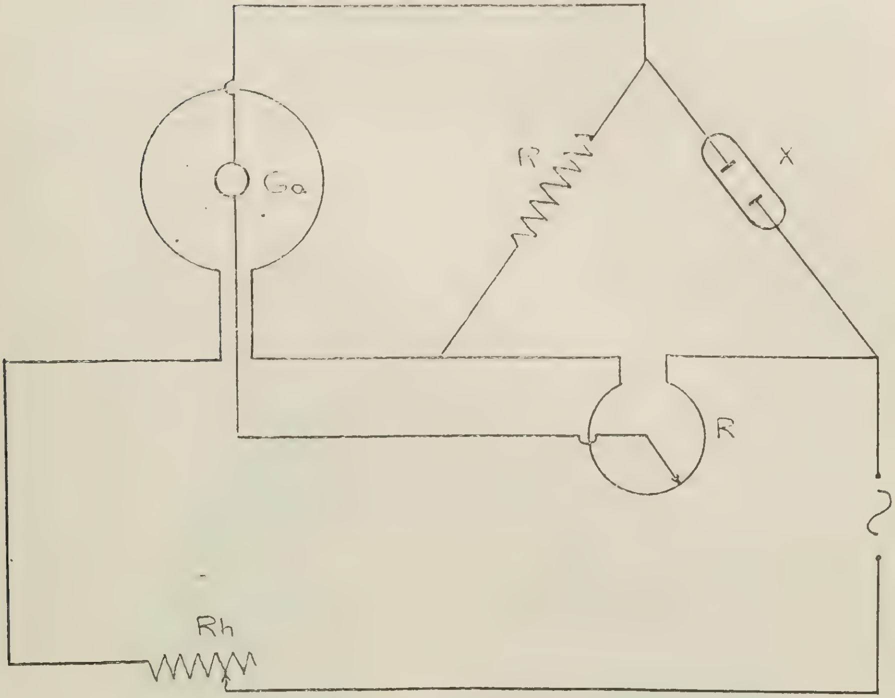

Fig. 9.
Scheme of connections when a galvanometer is used in the Wheatstone Bridge network.

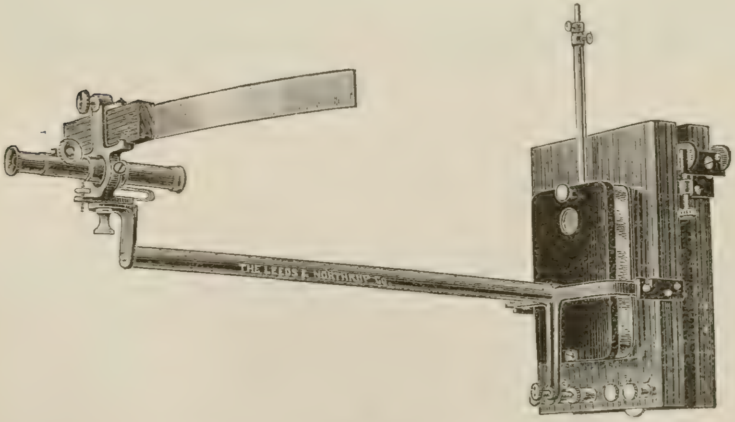

Fig. 10.
Detector. An alternating current galvanometer.

1/10 of an ampere for 10 second periods. Fig. 10 is a cut of the alternating current galvanometer used in these experiments.

When a galvanometer of the moving coil type is used, precautions must be taken against exterior electric fields. All such parts as produce this trouble should be incased in metal tubing or placed below the table. Until this was done the galvanometer scale was deflected as much as a scale division. This means an error of .1 of 1%. The data that accompanied the galvanometer make no mention of its sensitivity except when the stationary coil is so connected as to be in series with the swinging coil. Under this condition the sensitivity is .0027 amperes at 100 mm. Connected up in the other way the sensitivity is probably of the following order .000027 at 100 mm. A double contact switch on the top of the table and near the operator controls the galvanometer and bridge circuits. The circuit can be made and broken as the conditions require. It is never left on for more than a minute and usually only for a second or less. As soon as a deflection is noticed the circuit is broken and an adjustment of the bridge made. The circuit is again closed and the deflections of the scale observed. This operation is repeated until a balance is obtained. By this means errors from heating and polarization are elimin-

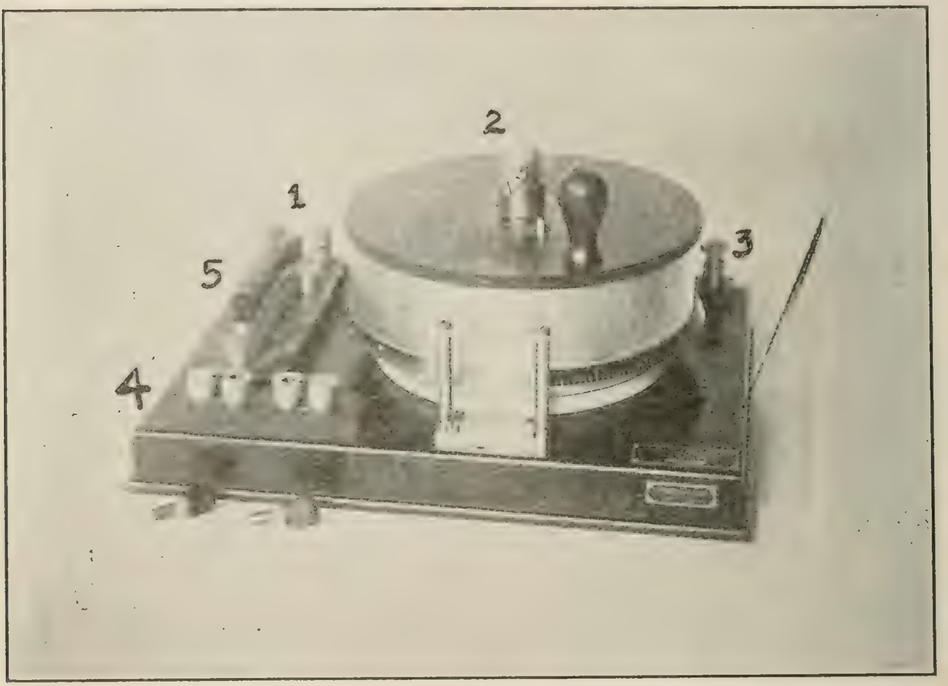

Fig. 11.
Bridge.

1. Posts for leads to electrolytic cell.
2. Posts behind drum for galvanometer leads.
3. Battery post.
4. Extension wire posts. "Extension" represented as in.
5. Resistance in bridge base. Disconnected.

ated. The connections on the double contact switch should be made so as to close the bridge circuit first and then the galvanometer circuit. A bottle of damping fluid is supplied with the instrument. Enough of this fluid is placed in the glass receptacle to cover the mica vane. The instrument is thus made aperiodic coming back to zero rapidly without over shooting.

BRIDGE.

The bridge, Fig. 11, is also made by the Leeds & Northrup Company. It is the latest improvement of the roller type. Kohlrausch (14) early showed that if an accuracy of .05 of 1% is desired the bridge wire would have to be extended. Two coils, non-inductively wound, each of which has a resistance of 4½ times that of the bridge wire itself, were placed at opposite ends of the wire. This constitutes the "extended bridge." The coils were so mounted on the bridge that by the removal of a couple of plugs the extension coils could be connected in. The rheostat coils usually found on this type of bridge were disconnected to avoid any error from capacity and inductance. The bridge has ten turns of wire upon its drum with a resistance of 7.157 ohms. Each extension has a value of 32.2 ohms thus making the resistance of the bridge wire and its extensions 71.557 ohms. A wire of low resistance and larger cross section is preferable to one that is very slight and slender because its calibration will remain more nearly constant. In addition it will stand wear and heavy treatment better.

There are a thousand scale divisions on the bridge and each one of these is divided into halves, making a scale of two thousand parts. Each of the smallest scale divisions is 3 mm. wide, and the bridge reading can be made to 1/5 part of this division without much difficulty. The error from a bridge reading will not be more than .002 of 1%.

The alternating current was first passed through a variable resistance in series with the bridge and then connected to the slider. The resistance was introduced in order to vary the current, for when the more concentrated solutions are used much less current is needed. If the full current was passed through, the heating of the electrolyte would follow, and result in a false reading on the bridge. The resistance is connected on one arm of the bridge and the electrolytic cell in the other. The swinging coils are placed across the bridge.

RESISTANCES.

The known resistances must of necessity be the best obtainable. These are the new Curtis Coils (Fig. 12). Their use was suggested to us after reading the article by Dr. Curtis (4) in a publication of the U. S. Bureau of Standards. According to a new method of winding the self-inductance and capacity of the coils are anulled. By request the Leeds & Northrup Company made for us a number of such coils of different values and assembled them in a box. Two of these boxes have been used in the experiments described in this paper. In assembling the coils in box form, it should be remembered that it is necessary to keep them sufficiently far apart to avoid any error from capacity. The newer "dial decade type" is more convenient and has a range of from 1 to over 100,000 ohms. A variable condenser (Fig. 12) must be introduced across the resistance to balance out the capacity in the electrolytic cup. This condenser must be chosen with a view to avoiding any leakage and therefore its insulation must be sufficiently high. An error of .2 of 1% is apt to occur from this cause. In making a measurement, take as much care to balance the capacities as you do to balance the resistances.

ELECTROLYTIC CELLS.

The cells used in these experiments were of different forms depending upon the purpose for which they were to be used. The materials from which they were made were Jena glass, hard vulcanite rubber, and platinum. Jena glass was chosen because it is one of the least soluble of all makes of glass. The slightest impurity from the glass or air causes an error in the resistance of the solution. The glassware was thoroughly cleaned by soaking it in a hot solution of potassium dichromate in sulphuric acid and afterwards rinsed in distilled water. The final treatment consisted in a steaming process for a few hours. "Conductivity water" showed no change in resistance after staying in cups prepared as above for a period of at least twenty-four hours. The hard vulcanite rubber parts were kept clean. The platinum was at least .35 mm. thick and rigidly fused to the glass connections. This prevented any change in the cell constant which would happen if the electrodes were in any way

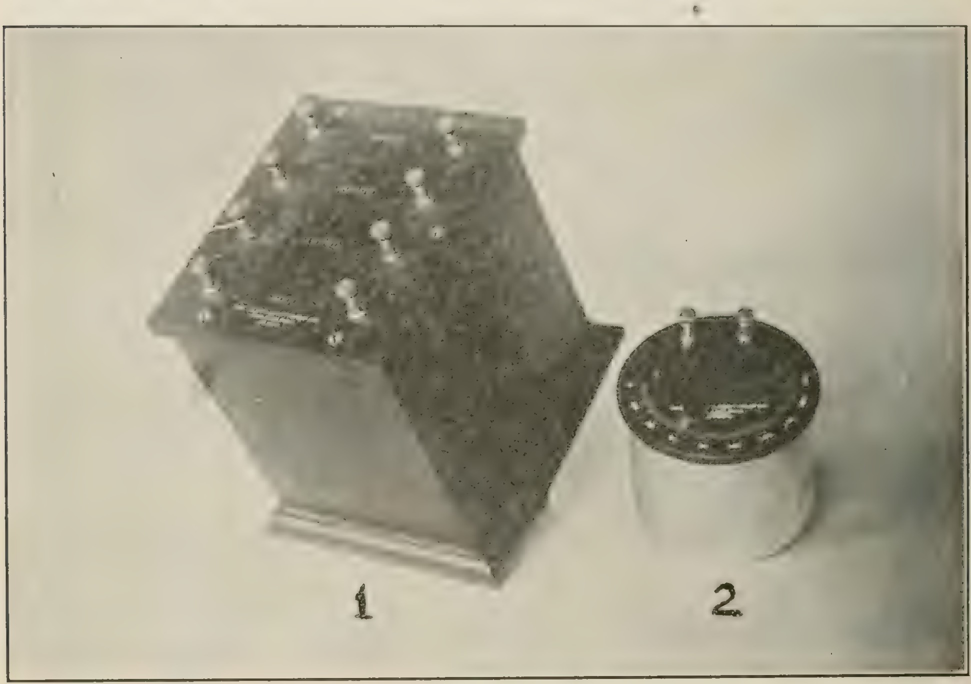

Fig. 12.

1. Resistance box. Curtis Coils.
2. Condenser.

dislodged from their original position in reference to each other and the sides of the glass container.

Platinized electrodes were used in all the tests and the platinizing was according to the usual method (5). When the electrodes receive a coat of platinum black their surfaces are immensely increased and polarization is negligible. The electrodes were frequently cleaned and replatinized. Dr. Clark of the University of Illinois has suggested that the cleaning process can be greatly facilitated by placing the electrodes in Aqua Regia with a reversal of the current every minute. It takes only a few minutes to clean them thoroughly. When not in use the electrodes are kept in conductivity water (about 2.0×10^{-6}). Before using the cells, they are tested for constancy and when two successive readings of conductivity water give the same figures, the cells are considered in proper condition to use.

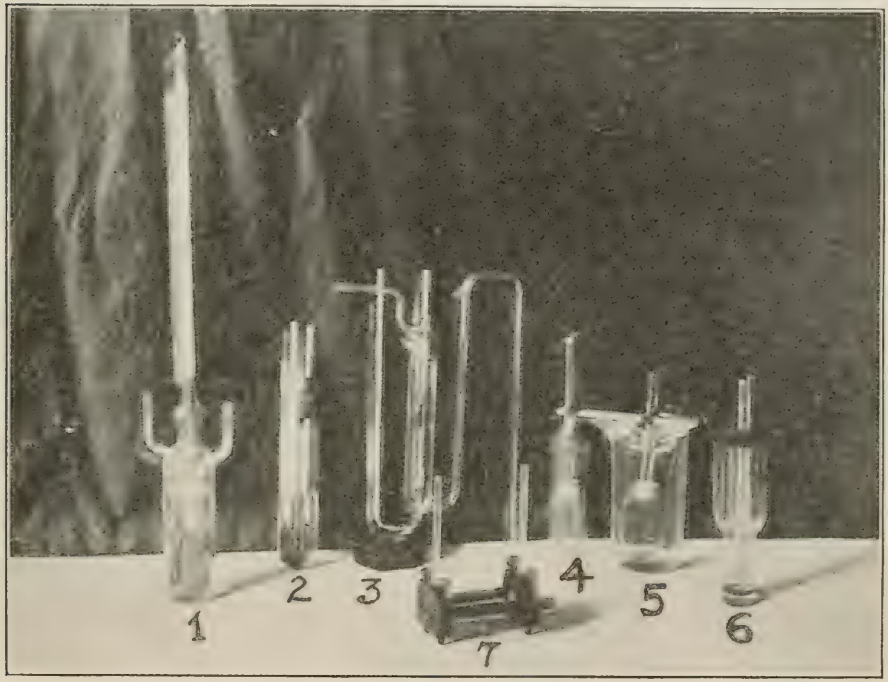

Fig. 13.
Resistance Cells.
Explanation of different types in text.

The various forms are shown in Fig. 13, Nos. 1, 4 and 5 are for solutions of low conductivity and Nos. 3 and 6 for high conductivity and No. 2 for medium conductivity. Nos. 4 and 5 are the plunger types to be used to determine the resistance of solutions in any size or form of beaker. This type eliminates the side effects. No. 7 is used when it is desired to measure the resistance of living tissues. Discs of the living tissues are prepared by using a cork-borer or other suitable device. These discs are then piled one upon another like a pile of pennies and clamped firmly between the electrodes. The pipette forms are similar to those figured in a paper by Washburn and MacInnes (43). It is preferable to have the electrodes vertical rather than horizontal for the quick removal of heat. It is advisable to immerse the bridge leads in tubes containing mercury, these tubes to be immersed in the bath so as to be at the same temperature as the cell. This reduces the passage of heat between the room and the cell.

THERMOSTAT.

The conductivity of a solution is greatly affected by temperature changes. A variation of one degree gives an error of 2% in the readings. It is necessary therefore to keep the temperature constant during conductivity measurements. For accurate measurements, a variation of .01 of a degree C. is not permissible. The best thermostat contains a large body of water to reduce the effect of temperature changes of the surrounding bodies. This water must be kept in constant motion and at a constant temperature.

Various devices for automatically regulating temperature have been tried. The really efficient one is electrical. The electrolytic cells are suspended in the bath and allowed to remain so for at least 10 minutes before a measurement is taken. Then the resistance, that is to balance the solution to be tested is adjusted, approximately. The bridge wire can be used alone or in combination with the "extensions." For accurate work the "extended wire" must be used. A modification of the Ostwald thermostat was used for preliminary work. This only kept the temperature constant to within a .1 of a degree. For accurate work the Freas water thermostat may be used. In this one the temperature is kept constant to .002 of a degree. A Beckmann thermometer should be suspended in any water bath as a check on the thermostat. The temperature of the bath was kept constant at 18° C.

4. METHOD OF OPERATION.

The following method of operation is suggested. See that the bath temperature is correct and constant. Select the cell that will be best suited for measuring the solution in question. Fill the cell and suspend it in the thermostat. When the solution is at the temperature of the bath a measurement may be made. Now start the rotary converter, being sure that the double contact switch which closes the bridge and galvanometer circuits is open. Throw in 500 or 1,000 ohms resistance in the variable rheostat so as to cut down the current entering the bridge. This will prevent excessive deflection of the galvanometer scale. Observe the zero point on the galvanometer scale and then close the galvanometer and bridge circuit switch for an instant. Note the direction of deflection. This will indicate whether the known resistance is too high or too low. Adjust the resistance to suit condition and close switch again. Repeat operation until balance is approximately obtained. Now vary the current on the bridge by adjusting the variable resistance until a maximum sensibility is obtained. At the same time adjust the condenser to balance out the capacity of the cup. Carefully adjust all three, the current, the resistance and the condenser and make a careful reading. Make another filling of the cell and repeat operations until checks are obtained.

5. EXPERIMENTAL.

The apparatus we have assembled is not only less tedious or trying to operate but shows a high degree of precision. We note below the data on a few experiments. It is not necessary at this time to publish at further length, for in this paper we wish only to describe the apparatus and its method of operation and draw attention to its applicability to biological problems and reserve for a future publication the experiments for which this apparatus was primarily devised.

Experiment I.

The object of this experiment is to show the precision that can be obtained when using certain values of known resistances, balanced against each other. The new Curtis Coils were used. In the table below one set of coils is designated as A and the other as B. The "perfect balance" is defined as that point at which the galvanometer scale does not move. Now if the bridge is moved .1 of a scale division either side of this point, a deflection of the galvanometer is seen. A tenth of a scale division is selected, as this is about the smallest deviation which can be estimated without the use of a micrometer screw, and magnifying glass. The "extended" E and "short" S bridge wires were used. The former is used when an accuracy of more than .05 per cent is desired. The latter is sufficient for all tests of culture solution.

GALVANOMETER METHOD.

No. of test.	Res. A.	Res. B.	Bridge.	Range.
1	5000 5000	5000 5000	S E	Perfect balance. Perfect balance.
2	10000 10000	10000 10000	S E	.2 scale division. .3 scale division.
3	20000 20000	20000 20000	S E	.4 scale division. .5 scale division.
4	35000 35000	35000 35000	S E	.7 scale division. .8 scale division.
5	55000 55000	55000 55000	S E	1.0 scale division. 2.25 scale division.

Experiment II.

The object of this experiment is to show the precision that can be obtained while using varying concentrations of KCl. The readings were made by one person.

A. Sol. M/10 KCl., E. Bridge, T. 18° C., Known Res. 26.6 ohms., Res. on bridge circuit 1,000. Conductivity cell No. II, electrodes platinized and 10 mm. apart.

No. reading	Res. ohms.	Bridge reading.
1	26.6	506.8
2	26.6	506.7
3	26.6	506.8
4	26.6	506.8

A "perfect balance" was obtained. In only one case was the reading .1 less than the others.

B. Sol. M/50 KCl, E. Bridge, T. 18° C., Known Res. 61 ohms., Resistance on bridge circuit 1,000 ohms. Conductivity cell No. I, electrodes platinized and 5 mm. apart.

No. reading	Res. ohms.	Bridge reading.
1	61	504.7
2	61	504.7
3	61	504.7

A "perfect balance" was obtained. No deviation.

C. Sol. M/1,000 KCl, E. Bridge, T. 18° C. Known Res. 1, 191 ohms., Res. on bridge circuit 400 ohms. Conductivity cell No. III, electrodes platinized and 6 mm. apart.

No. reading	Res. ohms.	Bridge reading.
1	1191	502.60
2	1191	502.60
3	1191	502.70

A "perfect balance" was obtained.

D. Sol. — twice distilled water, E. Bridge, T. 18° C., Known Res. 33,600 ohms. Resistance in bridge circuit, "out." Conductivity cup X, electrodes platinized and 2 mm. apart.

			Bridge reading.	
No. reading	Res. in ohms.	Left	Middle	Right
1	33,600	502.5	503.	503.5
2	33.600	502.5	503.	503.5
3	33,600	502.5	503.	503.5

Range of 1 scale division or .5 scale divisions on either side before deflection took place.

E. Conductivity water having a specific conductance of 1.7x10^{-6} ohms. at temperature of 18° C., E. Bridge, T. 18° C., Known Resistance 85,000 ohms. Res. in bridge circuit "out." Conductivity cup X. Electrodes platinized and 2 mm. apart.

			Bridge reading.	
No. reading	Res. in ohms.	Left	Middle	Right
1	85,000	497.	498.5	500.

Range of 3 scale divisions. Reading was made quickly. The switch was closed for only an instant at a time. This precaution was necessary as the thin film of solution between the electrodes was exposed to a heating effect of the current. By allowing the current to pass for only an instant the heating effect was found to be negligible.

Experiment III.

In D and E of the preceding experiment the range of scale divisions is 1 in one case and 3 in the other. For solutions of high resistance these results may be considered very good. An experiment was made however to see if the range could be shortened.

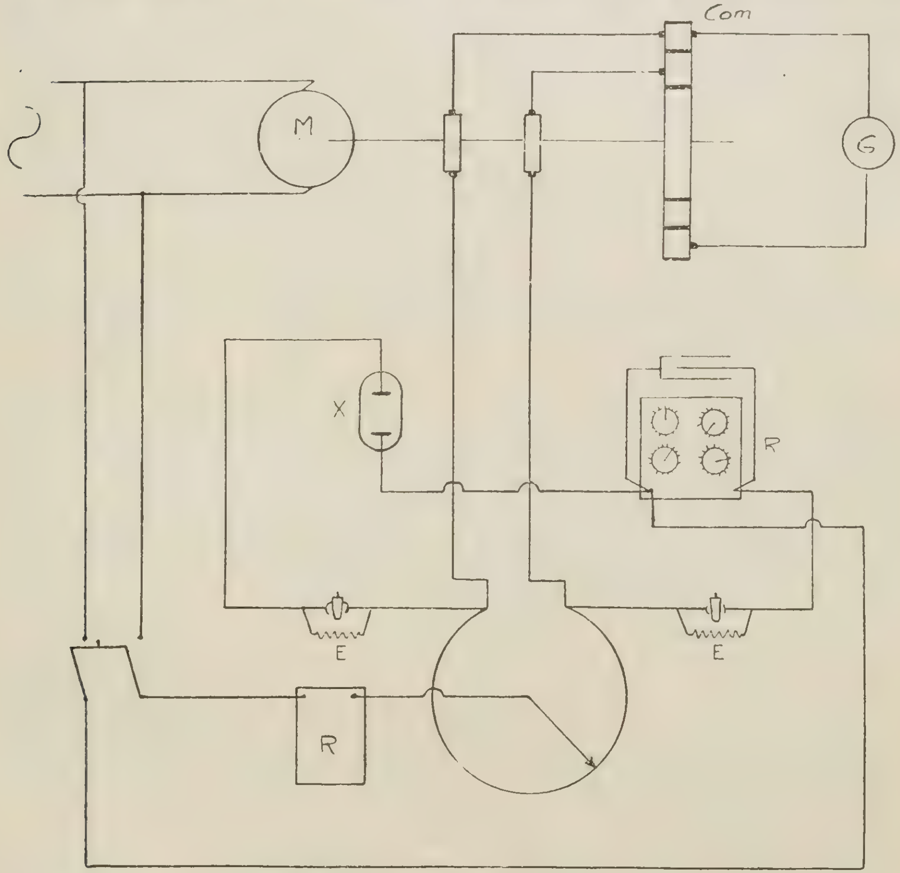

Fig. 14.
Arrangement and connection of parts when a D. C. galvanometer and rectifier are used.

It is a well known fact that a D. C. galvanometer is more sensitive than an A. C. galvanometer, but the former cannot be used with alternating currents. If, in some way, the alternating current can be rectified so as to become unidirectional then a D. C. galvanometer can be used. This change in current can be brought about by cutting out one of the phases of an alternating current. Devices that accomplish this are usually called rectifiers. There are a number of different forms but the most satisfactory one for this particular condition is the commutator. This is fastened upon the shaft of the rotary converter. Before an experiment is made this commutator is so adjusted as to eliminate one phase entirely. This adjustment must be made accurately as the value of all the work which follows is dependent upon it. The brushes must also be kept clean. Care in the above matters is necessary if the best results are to be obtained. Fig. 14 shows the set-up of the apparatus when the commutator and D. C. galvanometer are used.

For this experiment a water of rather low conductivity was selected. The resistance of this was determined by both the A. C. galvanometer method and the device which has just been described. The comparison is made from the standpoint of the range of scale divisions necessary for a reading.

A. Sol. Water of rather low conductivity, E. Bridge, T. 18° C., Known resistance 51,100 ohms. Resistance in bridge circuit "out." Conductivity cup X, electrodes platinized and 2 mm. apart.

Method	Bridge Reading Left	Middle	Right	Range
A. C. Galv.	500.	501.125	502.25	2.25
D. C. Galv. and commutator	509.	509.4	509.75	.75

This shows that the use of a D. C. galvanometer and commutator shortens the range of scale divisions and makes the reading more precise.

The condenser at hand, where this work was done, did not possess a low enough capacity. If a suitable condenser had been at hand the range of scale divisions would in all probability have been smaller.

B. Sol. M/50 KCl, E. Bridge, T. 18° C., Known Res. 55 ohms. Res. in bridge circuit unknown. A rheostat not graduated was used. Conductivity cup I, electrodes platinized and 5 mm. apart.

No. of reading	Bridge reading	Range
1	493	Perfect balance
2	493	Perfect balance
3	493	Perfect balance

The heating effect was completely eliminated by placing a variable resistance in the bridge circuit.

Experiment IV.

This experiment is reported in order to demonstrate the presence of heating effect, when the current load on the electrolyte is heavy. It also shows how effectively it is eliminated by introducing a resistance in the bridge circuit.

The solution was M/100 KCl, E. Bridge, T. 18° C., Known Res. 100 ohms, The conductivity cup with ground-in thermometer was similar to that of figure 2 pictured on page 14, Leitvermögen der Elektrolyte, by Kohlrausch and Holborn. The electrodes were platinized but the distance between them was not determined. The form was that of a hollow cylinder. The bath thermometer was a standard one with Reichsanstalt certificate and was graduated to tenths of a degree. The thermometer in the conductivity cup was graduated to tenths of a degree, but its accuracy is unknown. Since only relative changes are to be shown here extreme accuracy in temperature is not necessary. When the temperature of the bath was 18° C., that of the cup was 18.2° C. making a variation of .2 of a degree. The apparatus was first adjusted with the resistance in the bridge circuit and after a balance had been obtained the current was increased by a removal of the resistance. Immediately the scale deflected in one direction and gradually continued in the same direction. When the deflection reached the end of the scale the current was cut off and the time taken by a stop watch and the rise in temperature of the electrolyte noted. As an average of five tests the end of the scale was reached in 52 seconds and the temperature in that time had risen .8°. It may be mentioned here that when a resistance of 1,000 ohms was in the bridge circuit and the key down two minutes there was no deflection or "creeping" showing that the heating had been effectively eliminated.

The next two experiments are added in order to show the applicability of the conductivity apparatus described in the present paper to biological problems. As before, the intention is not to list a great number of experiments nor explain any in great detail. The method devised in this paper is adaptable to precise and delicate measurement of various biological phenomena.

Experiment V.

True (38) has shown that the resistance of distilled water decreases when seedlings of lupines or peas are grown in it, and attributes the fall of resistance to the excretion of electrolytes from the roots. His experiments touching on this point were repeated and confirmed.

Distilled water was used as a culture solution. This was put into thoroughly cleaned Jena glass beakers of 250 cc. capacity. The quantity of distilled water used in the beaker was 200 cc. Seedlings of Lupinus albus were used as indicators. The seeds were first soaked in the same water for about 16 hours, then adjusted on paraffined wire hooks which were hung from the edges of the beaker. The seeds were so adjusted that the hypocotyl would, on growing, reach the water in a vertical position. The beaker was covered with a glass plate so that moist conditions could be maintained. When the roots had reached the length of about 2 cm. the experiment was started. The seedlings while on the hooks were removed from this improvised germinator, washed thoroughly in fresh conductivity water and then suspended in the culture dishes. At the same time the electrodes were plunged into the solution and a reading made.

At 3 P. M. 3/13/15 the resistance was 29,595 ohms.
At 9:30 P. M. 3/13/15 the resistance was 24,945 ohms.
At 9 A. M. 3/14/15 the resistance was 19,393 ohms.
At 7:30 P. M. 3/14/15 the resistance was 16,125 ohms.
At 8:40 A. M. 3/15/15 the resistance was 15,210 ohms.
At 3:30 P. M. 3/15/15 the resistance was 13,735 ohms.

This experiment shows that the excretion of electrolytes was more rapid and in larger quantities at the beginning than at the end of the given period. It also shows that during a period of a little over 48 hours the resistance had fallen from 29,595 ohms to 13,735 ohms.

It is instructive to compare these results with the results obtained when tap water is the culture solution. The experiment is the same as the preceding in every respect except that the culture solution is tap water and the number of seedlings used thirteen.

At 9:30 A. M. 3/13/15 the resistance was 272.272 ohms.
At 11:40 A. M. 3/13/15 the resistance was 271.180 ohms.
At 2:00 P. M. 3/13/15 the resistance was 269.088 ohms.
At 9:20 P. M. 3/13/15 the resistance was 270.620 ohms.
At 9:30 A. M. 3/14/15 the resistance was 269.088 ohms.
At 3:30 P. M. 3/14/15 the resistance was 269.024 ohms.

During the 30 hours in which the experiment was running there was very little change in the resistance. The concentration seemed such as would allow absorption and excretion of electrolytes at equal rates.

Experiment VI.

For some time it has been known that roots excrete CO_2. To what extent the decrease in resistance is due to the presence of CO_2 is not definitely known. The following experiment shows, however, that the greater part is not due to the presence of CO_2 as might be thought. In this case about 13% of the change in concentration is probably due to carbon dioxide alone.

Three clean Jena glass beakers were selected. These three contained equal quantities of distilled water having the same conductivity. This was accomplished by washing them successively in conductivity water until the wash water possessed the same resistance as the original water. The experiment was then started. In the first beaker no seedlings were placed. Four seedlings were put in the second beaker and the third received eight. They were put aside for 24 hours and then the conductivities were determined. The seedlings were removed and the CO_2 driven off by heat. As much care as possible was taken not to decrease the volume of fluid but yet be sure of driving off the carbon dioxide. Pure hot melted paraffine was poured on immediately and the beaker of water so covered was put away in the ice chest for the paraffine to harden. Pure paraffin is inert chemically and no error larger than the experimental error is believed to enter here. After a few hours the beaker was placed in the water bath to bring the solution to the proper temperature. The paraffin cap was now removed and the conductivity of the solution measured.

Before Boiling.

No. seedlings	Bridge Reading	Resistance	Conductivity.
0	490	93,690	1.67×10^{-6}
4	442	26,182	5.98×10^{-6}
8	538	17,174	9.12×10^{-6}

After Boiling.

0	500	90,000	1.74×10^{-6}
4	570	30,112	5.20×10^{-6}
8	503	19,494	8.03×10^{-6}

The last column in the first series shows that after 24 hours the resistance of the water in which four seedlings had grown had decreased considerably over that in which no seedlings had grown. Likewise the resistance of the solution in which eight seedlings had grown is lower than that of the solution in which four seedlings had grown. It may also be observed that the decrease is not exactly proportional to the number of individuals growing in the solution. In the last column of the second series it may be noticed that the water in which no seedlings had grown had a slightly higher conductivity after boiling than before. No explanation is here offered. In the case of the other two culture solutions it is seen that boiling reduced the conductance by about 13% of what it was before boiling.

6. CONCLUSIONS.

In this paper the authors have endeavored to draw attention to the many biological problems, for the investigation of which the Wheatstone Bridge apparatus seems especially fitted. A plea is also made for a more general use of the principles of physical chemistry and a closer attention to the acquisition of quantitative rather than qualitative results.

Why this apparatus has not been more widely used, is in all probability due to the fact that it possesses, in its customary form a number of sources of error, which preclude accurate measurement. In addition, the taking of a measurement necessitates a considerable strain on the nerves of the operator. It is obviously very difficult to listen through a telephone for a point at which a continuous but gradually decreasing sound stops.

We have enumerated some of the errors inherent in the general method and believe that modifications, such as we have suggested make the apparatus much more precise as well as easier to operate. The induction coil was abandoned for a 60 cycle rotary converter, which gives a pure sine wave on a current of constant potential. The use of a frequency of 60 cycles per second was not attended with any appreciable error. It has been shown that in assuming polarization at 60 cycles we are assuming something neither apparent nor real. We have used this frequency for a period of two years, and have had no trouble from polarization but what could be eliminated.

The alternating current galvanometer is a better detector than the telephone for four reasons:—1. An exact balance can be made quickly and with ease. 2. Direction of deflection will indicate whether heating or polarization is taking place and the correction can be quickly made. 3. The circuit need not be closed more than an instant at a time and therefore the possible error due to heating or polarization is negligible. 4. The eye is more accurate than the ear. The customary resistance coils are replaced by Curtis Coils since these are wound for annulment of inductance and capacity. The dial decade type, a more recent form than the one used in these experiments is better because of the ease and convenience of manipulation. They also have as great a range and are better because the resistance can be increased by unit increments. Attention is drawn to the necessity of using the extended coils of the bridge if a greater accuracy than .05 of 1% is desired. It is preferable to use a bridge wire of rather low resistance as it can stand wear and heavy treatment better. It will also hold its calibration more certainly. In regard to the electrolytic cells, it may be said that their construction is of utmost importance. These cells act as capacities and to balance this, a condenser must be put in across the resistance in the adjacent arm. Cells with platinized electrodes are necessary when working with a frequency of 60 cycles per second. Too much attention cannot be given to the detail of maintaining a water bath at a constant temperature. A Freas water thermostat which is accurate to .002 of a degree is efficient for this work.

A method for operating the apparatus described in this paper is suggested and a few experiments added, to show the degree of precision obtained. This apparatus has proven efficient in our hands, and a measurement can be made quickly and easily. Besides this, the results show a high degree of precision.

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We also wish to acknowledge our indebtedness to Professor E. W. Washburn of the University of Illinois who kindly let us make some measurements with his apparatus, and who further kindly gave us blue prints illustrating the setup and the various connections used by him. We also wish to thank Professor A. R. Sawyer of the Michigan Agricultural College for the loan of various smaller pieces of apparatus when these were necessary in the two years of our investigations. He has also given us personal attention and advice and kindly read the manuscript.

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The mechanical drawings, Figures 1, 2, 3, 4, 5, 6, 9 and 14 were made by P. G. Andress of the class of 1916, Michigan Agricultural College.

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THE FREEZING POINT METHOD AS A NEW MEANS OF MEASURING THE CONCENTRATION OF THE SOIL SOLUTION DIRECTLY IN THE SOIL.

Technical Bulletin No. 24.

BY GEORGE J. BOUYOUCOS AND M. M. McCOOL.

INTRODUCTION.

A definite knowledge of the concentration of the soil solution as it actually exists in the soil, under all conditions, including variation in moisture content, tillage, fertilizer treatment, season, etc., is of the greatest importance and highest interest from all standpoints—the chemical, physical, physiological, and biological. At present, the exact concentration of the natural soil solution under all the conditions enumerated above is not known, as there has been no method capable of executing a direct measurement of its magnitude.

In the present bulletin there is presented the freezing point method as a new method capable of measuring the concentration of the soil solution directly in the soil under a variety of conditions, and some of the experimental data obtained.

REVIEW OF PREVIOUS METHODS.

A large number of methods have been used to ascertain the concentration of the natural soil solution, but nearly all of them are based upon the general principle of extracting or isolating the solution from the soil and measuring its concentration, besides other properties. The one method most extensively employed is that developed by Whitney and Cameron, (1), and consists of mixing 100 parts of soil with 500 parts of water, stirring the mixture vigorously for 3 minutes, allowing it to stand 20 minutes, and filtering the supernatant liquid through Chamberland-Pasteur filters under pressure. The results obtained by this method led Whitney and Cameron to advance the theory that the soluble mineral matter of the soils produces in general a saturated or nearly saturated solution in the soil moisture; that the magnitude of concentration of this soil solution is the same for practically all soils; and, that it is generally low, but sufficiently high for the growth and development of crops.

By employing the same method, other investigators have obtained different results and have arrived at different conclusions from those of Whitney and Cameron. One of the most extensive investigations upon the subject is that of King. (2). The results he obtained show that the amount of water-soluble material recovered in the water extract is large, and differs very widely in the various soils, and that the soils which produced the largest yields of crops or received application of fertilizers gave the largest amount of soluble material in the aqueous extracts.

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(1) Bul. 22, Bureau of Soils, U. S. Dept. of Agr., 1903.
(2) Bul. 26, Bureau of Soils, U. S. Dept. of Agr., 1905.

More recently, Hall, (3), et al., obtained results with the Rothamsted soils which agree in general with those of King. These investigators prepared artificial water extracts from certain Rothamsted experiment plots on which wheat and barley had been grown for 60 years and had received different manure treatment, by mixing 20 kgms. of dry soil with 30 kgms. of water. The results they obtained show that the concentration and composition of the soil solution are not constant but vary significantly in accordance with the composition of the soil, and its past manurial history.

This method, therefore, has apparently not only failed to give concordant results as to the concentration of the extract in the different soils, but also it tells nothing as to the exact concentration of the true solution of the soil. The addition of the water to the soil not only dilutes the natural soil solution, but also may cause a dissolving action upon the minerals, a suspension of the hydrosols, a dialysis of substances absorbed by hydrogels, etc.

Various investigators have attempted to obtain information regarding the concentration and composition of the soil solution by collecting and analyzing the drainage water of the soil. This method, however, is not only open to all the above objections, but also to the additional one that the drainage water may percolate through the spaces between the particles and may not come in complete intimate contact with the film of water around and in the soil particles, and since the processes of diffusion are slow, the drainage water may not be a true representative of the natural solution existing in the soil.

On account of the above objections to using water in isolating the natural soil solution, some investigators have tried to extract it directly from the soil by mechanical means. Two different methods have been employed to accomplish this purpose, namely, the centrifuge, and the paraffin oil. The centrifuge method has been developed and employed by Briggs, (4), and consists of whirling whetted soils in a rapidly revolving centrifuge fitted with concentric cylinders, the middle one having fine perforations, and developing a force equivalent, on the average, to 3,000 times the attraction of gravity. The soil solution is thrown out through the perforations and collects in the spaces between the perforated middle cylinder and outer cylinder. It collects usually as a perfectly clear solution, requiring no filtration. The results yielded by this method, however, have not been entirely satisfactory, owing: (1), to the small quantity of the soil solution obtainable at a time for analysis; (2), the liquid obtained is the excess or free water thrown out from the saturated soil and may not possess exactly the same concentration and composition as the film water remaining. That the concentration of the solution obtained might not be and probably could not be absolutely the same as the entire moisture of the soil, seems to be suggested by the following considerations: If the solution is not saturated or in equilibrium with the soil components, then the films which are in intimate contact with the surfaces of the soil grains would be more concentrated at any given time than the capillary or interstitial water, due to the slow rate of diffusion, and if only the interstitial water is extracted then the concentration of the extract would be less than that of the entire moisture existing in the soil. Furthermore, since the soil is a mixture of different minerals and the rate of diffusion is extremely slow, especially in the soil system, the different mineral particles would have films of different concentration, and if not all of these films are extracted or truly represented in the extract, the latter, of course, would not possess exactly the same concentration as the entire soil moisture. Again, due to the phenomenon of adsorbtion it has been suggested that that portion of the moisture immediately at the surface of the particles is more concentrated than the bulk of the solution. Whether or not this last concept is true cannot be proved; but it would seem that when a substance, be it liquid or solid, is adsorbed, becomes inoperative or inactive. (3). There is no excellent reason to believe that the solution obtained from a saturated soil will have both the same concentration and composition as the moisture of the soil short of saturation.

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(3) Jour. Agr. Sci. 6, 1914.
(4) Buls. 22 and 31, Bureau of Soils, U. S. Dept. of Agr., 1905 and 1906 respectively.

The paraffin oil method consists of replacing the excess of soil water with paraffin oil under pressure or suction. This method has been developed by Van Suchtelen and Itano (5), and Morgan (6), and is a modification of Ischerekov's method, (7), wherein he employed alcohol. Although a complete report of the results obtained by this method has not yet appeared, it would appear, however, from many theoretical principles as well as from some preliminary data already published (6), that this method is capable of extracting only a limited amount of the soil solution present in the soil and especially in the heavy types of soil and, consequently is open practically to the same objections as the centrifuge method.

From the foregoing brief exposition of the different methods now in vogue for studying the soil solution, it becomes very obvious that none of them is capable of furnishing definite information, either as to the actual concentration or composition of the natural soil solution as it exists in the soil under different conditions, including variation in moisture content, season, tillage, fertilizer treatment, etc. Nor does it seem possible or hopeful that they will ever be able to attain this object so long as their principle is based upon isolating the natural soil solution from the soil. From mechanical principles alone it would seem hopeless to expect to ever execute a complete separation between liquid and solid phases of the soil, or even a partial separation at the lower magnitudes of water content.

The next logical course that would suggest itself for obtaining a more definite information, either as to the actual concentration or composition of the natural soil solution, is to study the latter in the soil itself. Such study should give all the information desired and ought to be devoid of all the objections applicable to the other methods. Any method, therefore, capable of furnishing such definite information, either as to the concentration or composition, or both, of the natural soil solution under all circumstances, would be of the greatest service. From theoretical considerations, however, probably no method could ever be expected to ascertain directly the composition of the natural soil solution in the soil, but it might, the concentration.

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(5) Journal f. Landw. Band 60. Seite 369-370, 1912.
(6) Michigan Board of Agriculture Reports, 1913, p. 149, and 1914 p. 210.
(7) Russian Journal f. Landw. 8, 1907, No. 2 147-66.

A method now in vogue, which would seem at the outset of being capable of measuring the concentration of the natural soil solution in the soil, is the electrical bridge, as developed by the U. S. Bureau of Soils, (8), for the determination of soluble salts in soils. The principle of this method is dependent upon the fact that the electric current is conducted by the salt solution or its ions, and the conduction of the solution or conversely, its resistance to the passage of the current, being determined largely by its concentration.

Unfortunately, the general utility of this method in soil work is very much limited owing to the large number of factors involved in the soil medium which influence the conductivity of the electric current. It has been found, for instance, that the fine particles of the soil increase the resistance, due undoubtedly to the lengthening of the path between the electrodes by the increase in curvature of the grains. The resistance is also influenced by the thinness of the water films. These water films lose the properties of liquid in mass when they become too thin, and together with the capillary spaces in the soil, offer a greater resistance to the electric current. Furthermore, it has been found that the presence of carbonates and organic matter also materially increase the resistance of the soil solution in the soil.

From these facts, it is evident, then, that the electrical bridge cannot be used to ascertain the concentration of the soil solution with much reliance; this is not only true with soil short of saturation, but also with saturated soils. Hence, some other method is needed to measure the concentration of the soil solution in the soil.

THE FREEZING POINT METHOD AS A NEW MEANS.

In conducting a thorough investigation on the general subject of soil temperature at this Station, the influence of soluble salts on the lowering of the freezing point of soils was also studied. It was observed that the phenomena of supercooling and freezing behave in moist soils exactly the same way as in solutions. These facts suggested at once the idea that the freezing point method might be employed to measure the concentration of the natural soil solution in the soil itself. In order to ascertain whether or not this could possibly be done, a series of preliminary experiments was instituted, using different classes of soil with various moisture contents or known concentrations of solutions. The procedure consisted of placing a short column of soil in a narrow glass tube, inserting the bulb of the thermometer in this column of soil, allowing the soil mass to supercool and moving the thermometer in the soil to start solidification. It was discovered that the freezing point lowering of the soil solution in the soil, could be determined with great ease. Solidification could be started when the soil mass was supercooled to only about 0.3°C by simply moving the thermometer slightly in the soil. The lowering of the freezing point could be determined in soils from any maximum moisture content down to or below the wilting coefficient of plants. In the case of quartz sand, for instance, the lowering of the freezing point could be measured when the moisture content was only 0.7%.

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(8) Buls. 8 and 16, Bur. of Soils, U. S. Dept. of Agr., 1897 and 1910 respectively.

In every respect, therefore, the method appeared so promising from these preliminary trials of being capable of measuring the concentration of the real soil solution, that a more thorough investigation was instituted, employing a greater number of soils at different moisture contents and treating some of the soils with a large number of chemical compounds of the same concentration in order to ascertain what effect the application of soluble salts has upon the concentration of the soil solution. The results obtained are in many respects very remarkable and unexpected and promise to give us a better understanding of the

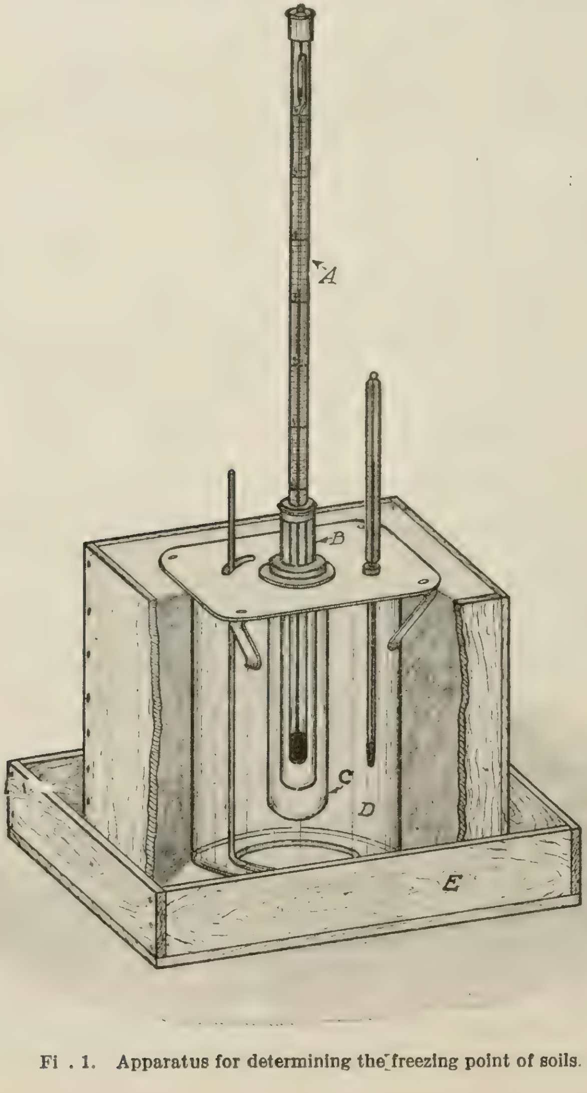

Fig. 1. Apparatus for determining the freezing point of soils.

fundamental principles governing the soil solution. In the following pages, therefore, there are presented a complete description of the method and the experimental data obtained.

DESCRIPTION OF THE METHOD.

The lowering of the freezing point of soils and consequently the concentration of their solution were determined by the use of the Beckmann apparatus with certain modifications. The complete apparatus employed is shown in Figure 1. A is the Beckmann thermometer. Its whole scale is composed of only 5.860°C. Each degree is divided directly into 100 parts, and with the assistance of a pair of lenses, the readings can be made to .001°C. B is a glass tube 1 inch in diameter and 9 inches long, and contains the soil. The thermometer passes through a rubber stopper at the mouth of the tube and its bulb is inserted in the soil column until it is entirely covered. The tube B passes through a rubber stopper into the wider glass tube, C, which is 1.5 inches in diameter and 6 inches long, and acts as an air jacket to prevent rapid cooling or radiation from the soil by preventing it from coming in intimate contact with the cooling mixture contained in the battery jar, D. In order to reduce as much heat ratiation as possible from the cooling mixture and thus keep its temperature more constant, the battery jar is placed in a small wooden box and packed around with excelsior. The wooden box, having a hole at the bottom, allowed to drain into the pan, E, any water that might have fallen into it during the operation of filling the battery jar with the ice and water. F is a common thermometer which indicates the temperature of the cooling bath.

For performing a freezing point determination the following procedure was always followed. The battery jar was filled with crushed ice. To this ice was added some water and sufficient salt, usually NaCl, to produce a temperature of about —4.5°C. The Beckmann thermometer was set so that the mercury thread would come to rest towards the upper part of the scale when the bulb was held in the mixture of pure ice and distilled water, and then calibrated with distilled water. The freezing point of distilled water was taken as zero, and the lowering of the freezing of soils was obtained by getting the difference between the freezing point reading of the distilled water and that of the soil. The freezing point reading of the soil was determined by placing about one inch column of soil in the glass tube, and then inserting the bulb of the thermometer into this column of soil until it was completely covered. The tube containing the soil and the thermometer was placed into the air jacket and allowed to cool in the cooling bath. The temperature of the soil was allowed to fall until it was about 1°C lower than the freezing point of the soil, i. e., supercooled. In order to start solidification, the soil tube was held firmly with the left hand near its mouth, and with the right hand, the thermometer was moved or rotated toward and away from the operator, until the temperature began to rise. The temperature was allowed to rise until it came to rest at a certain point on the scale and remained at that point for some length of time. This maximum temperature attained was considered as the proper freezing point of the soil and recorded. The thermometer was always tapped before taking the final reading.

It was discovered very soon at the beginning that it required a very long time for the soil to cool in the air jacket, owing to the poor heat conductivity of the air in the jacket. It was finally decided to hasten the process by bringing the tube containing the soil and the thermometer in intimate contact with the cooling mixture and allowing the soil mass to cool to about 5°C above the freezing point of water, or until there was only a small amount of mercury at the upper part of the reservoir, and then taking out the soil tube from the cooling mixture and inserting it at once into the air jacket and letting the soil mass to cool slowly. This procedure, however, was generally successful when the soils contained a high moisture content, but not when they had a low water content. In the latter case solidification would commence before supercooling had taken place and the proper lowering of the freezing point could not, of course, be determined. The plan, therefore, was modified, and in its final form consisted of cooling the soil directly in the cooling mixture until all the mercury had left the reservoir and then taking that portion of the tube containing the soil between the palm of the hand and warming it until the mercury thread began to rise again. The tube was then placed into the air jacket in the cooling bath and allowed the soil to cool gradually. The process of warming the soil slightly after it was taken from the cooling mixture proved a great success as it almost always prevented the occurence of solidification before supercooling had taken place. With the above plan in its final form, therefore, the time required for making a freezing point determination was reduced about 60%, and as many as 30 freezing point determinations have been made in one day—8 hours.

For taking off the initial excess of heat from the soil system it was found convenient to employ a second battery jar containing a cooling mixture of the same temperature as the first.

It was found very essential to allow the soil to supercool to about 1°C below its freezing point, although solidification could be induced at the supercooling of only about 0.3°C, in order to obtain quicker and more accurate readings. By supercooling the soil to about 1°C, sufficient solid or crystal ice of the pure soil water is immediately separated to warm the soil system quickly up to its proper freezing point. If the amount of the supercooling is small, the separation of the solvent is very slow, the thermometer comes to rest only very slowly, and the readings obtained are not accurate, especially with soils of low moisture content.

On the other hand, too much supercooling is also a source of error, and especially if the soil solution is highly concentrated. The freezing point of a solution is the temperature at which ice and solution exist in equilibrium. Upon freezing, pure water separates in the solid phase, and the liquid which remains, and whose temperature in equilibrium with the mass of the ice crystals, is read from the thermometer, is not the same, but more concentrated than the original solution. In consequence, the observed depression of the freezing point is lower than the true lowering of the freezing point of the solution under investigation. The amount of solid solvent formed depends upon the amount of supercooling and the heat of solidification of the solvent, which is obviously equal to its heat of fusion. The greater the undercooling, therefore, and the larger the amount of ice that will separate at the moment of freezing, the greater will be the concentration of the remaining solution, and, consequently, the larger will be the error on the lowering of the freezing point. In order to compensate for this source of error as much as possible, a correction may be introduced. Let u be the undercooling of the solution in degrees, s, the specific heat of the liquid, and l, the latent heat of fusion of unit weight of the solvent; then, $\frac{su}{l} = f$, where f is the amount by which the solution will be concentrated, due to the separation of ice.

While this formula may be applicable in case of solutions in mass, it was not considered to be so in soils, and consequently it was not employed in the final determination of the lowering of the freezing point of soils. The error arising from this source, however, is not great enough to affect the results very appreciably considering the amount of undercooling employed.

The length of time at which the mercury column remained at the proper freezing point seems to be inversely proportional to the concentration of the soil solution. This phenomenon is, of course, due to the separation of the solid solvent which causes the solution to become more concentrated and lowers its freezing point. When the soil solution is very dilute, the relative mass of pure water is large, and the time required for all of it to freeze in the solid phase so that the freezing point may sink, is very long. Hence, the real freezing point remains at its place a long time. When the soil solution is concentrated, however, the relative mass of the pure solvent is not large, and a small quantity of ice separated, concentrates the mass of the solution and lowers the freezing point, hence, the length of period during which the actual freezing point remains at its place, is short. The time varies from several minutes, in the soil with high moisture content, to less than a minute in the soil with a very low water content.

It has already been stated that the temperature of the cooling bath was maintained at about —4.5°C. It was found that if the temperature was lower than this the rate of cooling of the soil mass would be too rapid and solidification would commence before supercooling had occurred. The temperature then would descend very slowly and the proper lowering of the freezing point could not be determined accurately. On the other hand, if the temperature was less than —4.5° the soil mass would cool very slowly, and consequently, would take much longer to make a freezing point determination.

From theoretical reasons, a too low temperature in the cooling bath involves an error in the final reading owing to the radiation and conduction of heat from the soil. The greater the difference in temperature between that of the soil system and the cooling bath the greater is the amount of radiation from the soil and consequently the lowering of the freezing point will be slightly greater. The amount of error arising from this source, however, is also very small.

As previously mentioned, the lowering of the freezing point of soils could be measured from any maximum water content down to a very low water content, probably lower than at the wilting coefficient of plants. Below this last lower limit, solidification could not be induced very readily. At the high moisture content duplicate determinations of the same sample would agree exactly with one another, or vary only a few thousandths of a degree. At the low moisture content, however, the duplicate determinations of the same sample would agree only with some soils, such as the quartz sand and sandy soils, but with other soils, such as the clay and loam, the variation would be considerable, but always consistent, namely, the first lowering of the freezing point was always greater than the second. The duplicate determination of different samples of the same soil, however, would agree very closely, even with the latter soils. The probable reason for the change or decrease in the lowering of the freezing point with successive freezings in the case of colloidal soils at low moisture content will be offered subsequently.

Great care was always exercised to secure as uniform moisture content throughout the entire sample of soil under investigation, as possible. It was recognized that if some particles of the soil sample were not moistened the lowering of the freezing point would be less, because not all of the soluble material would be in solution. The soil sample short of saturation, therefore, was prepared by passing it through a sieve several times and mixing it thoroughly with the fingers. Even then, it cannot be said that all of the soil grains were moistened exactly to the same extent, but if they were all sufficiently moist so that their film would freeze upon supercooling then the freezing point depression observed would be an average of the lowering of the freezing of the various particles. The soil samples which contained high moisture contents and could not be passed through the sieve, especially if they consisted of the colloidal types, were thoroughly worked with the fingers. Great precaution was taken, of course, to have the latter thoroughly clean. There is some danger of salts being added to the soil through perspiration of the fingers, but the amount would be so insignificant that it could never be detected by the method.

It was feared at the outset that on account of the compressability of the mercury bulb great errors might be caused by the expansion of the soil upon freezing. A thorough examination of this point, however, proved that an error might arise from this source only when the soil in the tube was extremely compacted, but otherwise there is none. To guard against any possibility of error of this nature, however, the soil in the tube was only slightly compacted and the bulb of the thermometer was always moved in the soil at the beginning so that it would be loose.

In calibrating the thermometer with distilled water and attempting to keep it at that set point for several days, it was found that it would not remain the same, but would change. This change was not always in the same direction, but varied in both directions. In examining several treatises on thermometry, no mention was made of this fact, and could not be accounted for at the beginning of the investigation. It was soon discovered, however, that it was caused by the difference in temperature of the room in which the thermometer was calibrated at the different days. Thus if the room temperature was 20° on one day and 25° on another day the freezing point of the same distilled water would be different and indeed the reading on the thermometer would be greater at the highest temperature. When the room temperature, however, remained unchanged, exactly the same freezing point of the distilled water would be obtained every day for a long time. Evidently the room temperature influences the exposed mercury column. This effect, however, is not the same as that due to the emergent column. The magnitude of the change depends upon the difference in the temperature. Preliminary experiments showed that a temperature difference of ± 10°C caused a change of ± .020°C on the freezing point of water. If it is desired to save time by not calibrating the thermometer too often a correction such as the above could be worked out and applied to the readings obtained. In the present investigation, however, the room temperature remained quite constant and it was not necessary to apply a correction.

EXPERIMENTAL DATA.

The Lowering of the Freezing Point of Soils at Different Moisture Contents; and under Other Conditions.

In accordance with the foregoing method and the necessary precautions mentioned, the lowering of the freezing point of a large number of soils was determined. In the present paper, however, only the results of typical representatives of diverse classes of soil are presented with the view of showing mainly the character of results that this method yields. All the soils employed, with the exception of quartz sand and kalolin, were taken from the field and were consequently in the natural state. Since preliminary trials showed that the lowering of the freezing point varied with the moisture content, it was decided to measure the former in each soil at two different moisture contents, low and high. These two different degrees of water content were arbitrarily chosen for purposes of comparison, and are not exactly equivalent for the various types of soil. The low moisture content does not indicate the lowest limit at which solidification would occur, for in many of the soils the water content could well have been reduced considerably more, but at this low degree of water content the solidification could be induced very readily and the readings could be absolutely depended upon. The high moisture content may be taken to represent the point of saturation. In order to secure these two extreme and opposite degrees of water content, water was either added to the soil, if it was not already saturated when taken from the field, or withdrawn from it by spreading it in a thin layer and allowing it to lose water until the desired moisture content was reached. In many cases the soil as taken from the field was sufficiently dry to be used immediately for the freezing point determination. The majority of the soils presented in Table 1 were collected in the vicinity of this College, a few were sent in from other counties of the State, and they all constitute the upper 6-inch layer of the field.

In order to obtain an idea as to the magnitude of concentration and osmotic pressure that the depressions of the freezing point represent at the opposite extreme moisture contents, the values of both of these factors have been calculated and are presented together with their respective depressions of the freezing point. The concentration is expressed in parts per million of solution and was calculated directly from soil water extracts and not from any particular pure chemical compound or combinations therefrom. The procedure for accomplishing this consisted of mixing a large amount of soil with a small quantity of water, allowing the mixture to stand for about two days with occasional stirring, and then filtering the solution through a filter paper. A portion of this solution was used to measure its lowering of the freezing point and the remainder was employed to determine its total solid matter by evaporating a definite volume of it to dryness and weighing the residue. From the freezing point depression of the extract and its corresponding amount of solid material present, the concentration in p. p. m. of solution that might be represented by the values of the lowering of the freezing point of each soil was calculated. There were three different types of soil from which water extracts were made; namely, clay, loam and peat. It was found by calculation that 100 p. p. m. of solid material in the soil water extract gave the following values of the lowering of the freezing point; clay, .0038°, loam .0030°, and peat .0031°C. Evidently equal concentration of the water extracts of these three different types of soil caused about the same lowering of the freezing point. This is extremely interesting in view of the fact that on account of the marked difference in the physical and chemical composition of these soil types entirely different results might have been expected. On account of this remarkable closeness of the lowering of the freezing point for all three soil extracts, an average was taken in the computation of the concentration of the soil solution of the various soils as represented by their lowering of the freezing point.

It is readily realized that the foregoing procedure of estimating the magnitude of concentration that the various values of the freezing point depression might represent is open to many objections, but it is believed that it is perhaps the best way of obtaining an idea as to the magnitude of this value.

The osmotic pressure was calculated from a table of osmotic pressures as worked out by Harris and Gortner, (9), from the formula $\pi = 12.06\triangle - 0.021\triangle^2$, where π is the osmotic pressure in atmospheres, and $\triangle$ is the lowering of the freezing point in centigrade degrees. For convenience and usefulness this table is reproduced herewith.

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(9) Am. Jour. Bot. 1, 75-78, 1914.

Table 1. Osmotic Pressure in Atmospheres for Depression of the Freezing Point to 2.999° C.

△	Hundredths of Degrees, Centigrade.									
	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.121	0.241	0.362	0.482	0.603	0.724	0.844	0.965	1.085
0.1	1.206	1.327	1.447	1.458	1.688	1.809	1.930	2.050	2.171	2.291
0.2	2.412	2.532	2.652	2.772	2.893	3.014	3.134	3.255	3.375	3.496
0.3	3.616	3.737	3.857	3.978	4.098	4.219	4.339	4.459	4.580	4.700
0.4	4.821	4.941	5.062	5.182	5.302	5.423	5.543	5.664	5.784	5.904
0.5	6.025	6.145	6.266	6.386	6.506	6.628	6.747	6.867	6.988	7.108
0.6	7.229	7.349	7.469	7.590	7.710	7.830	7.951	8.071	8.191	8.312
0.7	8.432	8.552	8.672	8.793	8.913	9.033	9.154	9.274	9.394	9.514
0.8	9.635	9.755	9.875	9.995	10.12	10.24	10.36	10.48	10.60	10.72
0.9	10.84	10.96	11.08	11.20	11.32	11.44	11.56	11.68	11.80	11.92
1.0	12.04	12.16	12.28	12.40	12.52	12.64	12.76	12.88	13.00	13.12
1.1	13.24	13.36	13.48	13.60	13.72	13.84	13.96	14.08	14.20	14.32
1.2	14.44	14.56	14.68	14.80	14.92	15.04	15.16	15.28	15.40	15.52
1.3	15.64	15.76	15.88	16.00	16.12	16.24	16.36	16.48	16.60	16.72
1.4	16.84	16.96	17.08	17.20	17.32	17.44	17.56	17.68	17.80	17.92
1.5	18.04	18.16	18.28	18.40	18.52	18.64	18.76	18.88	19.00	19.12
1.6	19.24	19.36	19.48	19.60	19.72	19.84	19.96	20.08	20.20	20.32
1.7	20.44	20.56	20.68	20.80	20.92	21.04	21.16	21.28	21.40	21.52
1.8	21.64	21.76	21.88	22.00	22.12	22.24	22.36	22.48	22.60	22.72
1.9	22.84	22.96	23.08	23.20	23.82	23.44	23.56	23.68	23.80	23.92
2.0	24.04	24.16	24.28	24.40	24.52	24.63	24.75	24.87	24.99	25.11
2.1	25.23	25.35	25.47	25.59	25.71	25.83	25.95	26.07	26.19	26.31
2.2	26.43	26.55	26.67	26.79	26.91	27.03	27.15	27.27	27.39	27.51
2.3	27.63	27.75	25.87	27.99	28.11	28.23	28.34	28.46	28.58	28.70
2.4	28.82	28.94	29.06	29.18	29.30	29.42	29.54	29.66	29.78	29.90
2.5	30.02	30.14	30.26	30.38	30.50	30.62	30.74	30.86	30.98	31.09
2.6	31.21	31.33	31.45	31.57	31.69	31.81	31.93	32.05	32.17	32.29
2.7	32.41	32.53	32.65	32.77	32.89	33.00	33.13	33.25	33.36	33.48
2.8	33.60	33.72	33.84	33.96	34.08	34.20	34.31	34.43	34.56	34.68
2.9	34.79	34.91	35.04	35.16	35.27	35.39	35.51	35.63	35.75	35.87

The osmotic pressures corresponding to depressions of hundredths of degrees may be read directly from the table. Furthermore, for all practical purposes the first differences x 0.1 may be taken as 0.012, hence, pressures when △ is read to thousandths of a degree may be at once determined. Thus. suppose △ to be 1.224°. For △ = 1.24° pressure = 14.92°. 14.92 (4 x 0.012) = 14.968.

The lowering of the freezing point of various types of soils, then, at two different moisture contents, together with the calculated concentration in p. p. m. of solution and osmotic pressure in atmospheres that these values of the freezing point depression might represent, are shown in Table 2.

Table 2. Lowerings of the Freezing Point and their Corresponding Concentration and Osmotic Pressure of Various Types of Soil.

Name of Soil.	Quartz sand.		Sand.		Sand.		Sand.		Sandy loam.		Sandy loam.		Sandy loam.		Sandy loam.		Loam.		Loam.		Loam.		Loam.	
Percentage of Moisture....	1.50	15.0	2.60	21.98	4.44	23.80	6.03	23.00	4.79	19.30	10.33	24.50	8.35	23.09	8.30	21.53	16.39	35.84	11.18	20.97	16.77	31.41	18.83	33.18
Freezing point Depression...	.070	.007	.130	.010	.060	.010	.100	.010	.210	.015	.137	.012	.470	.025	.450	.020	.830	.022	.455	.028	.810	.025	.420	.025
Parts per Million......	2,121	212	3,939	303	1,818	303	3,030	303	6,364	455	4,152	364	14,244	758	13,636	606	25,154	667	13,780	848	24,546	758	12,728	758
Osmotic Pressure.....	.844	.084	1.568	.121	.724	.121	1.206	.121	2.532	.181	1.652	.145	5.664	.301	5.302	.241	9.995	.265	5.483	.337	9.755	.301	5.062	.301

Name of Soil.	Silt loam.		Silt loam.		Clay.		Clay.		Clay.		Clay.		Clay loam.		Clyde loam.		Clay loam.		Kaolin.		Peat.		Peat.	
Percentage of Moisture....	17.40	34.76	13.09	30.00	18.80	36.50	22.91	59.02	23.10	63.43	15.42	30.50	18.52	30.32	22.91	39.85	26.28	49.13	13.50	78.60	138.97	186.94	122.1	360.2
Freezing Point Depression...	.665	.035	.352	.022	.955	.034	.825	.020	.845	.010	.462	.020	.755	.025	.825	.050	.365	.015	1.025	.025	.050	.003	.062	.002
Parts per Million......	20,153	1,061	10,667	667	28,940	1,030	25,003	606	25,606	303	14,000	606	22,880	758	25,003	1,515	11,060	455	31,060	758	1,515	91	1,879	61
Osmotic Pressure.....	8.011	.422	4.243	.265	12.04	.410	9.935	.241	10.72	.121	5.567	.241	9.093	.301	9.935	.603	4 3 99	.181	12.340	.301	.603	.036	.748	.024

From a careful examination and consideration of the above results it will at once be recognized that they are extremely unusual and indeed almost incredible, in view of the present ideas concerning the soil solution. They show, for example, that at the high moisture content, the lowering of the freezing point and consequently the concentration, are very small and only slightly different for the various classes of soil, but at the low moisture content, the lowering of the freezing point and consequently also the concentration, are extraordinarily high and very different for the same classes of soil as above. Thus, at the high water content, the magnitude of the lowering of the freezing point varies from .003°C in case of the peat, to 0.050°C in humus loam, but the mean for the majority of the soils is around 0.010° and 0.020°C. At the low moisture content, however, the magnitude of the depression varies from 0.070°C in the case of washed quartz sand of medium texture, to 0.955°C in medium heavy clay, and tends to increase from soils composed mainly of pure silica, to soils containing complex aluminum-silicates and organic matter.

These values of the freezing point depression at the low moisture content would have been still greater had the moisture content been farther lowered. It is to be noted, however, that with some soils, the lowering of the freezing point could not be much more increased with further reduction in water content because they have approached the point of dryness. Thus, the quartz sand and one of the sandy soils contain only 1.5 and 2.6% of water, respectively. While many of the clays and clay loams contain as much as 20% and one of the peats, 138.97% moisture. Yet, when the quartz sand and sandy soils have reached the point of dryness, their maximum lowering of the freezing point is only about 0.100°C, while that of the clays and clay loams, whose moisture content is more than enough to saturate these sandy soils, give a lowering of the freezing point close to 1.000°C, or ten times greater.

The concentration that the lowering of the freezing point at the low moisture content of the more complex soils represents, is really tremendous. Thus, the depression of .935°C in one of the clay soils represents a concentration, as calculated by the method already described, of 28,940 p. p. m. and an osmotic pressure of 12.04 atmospheres. These great magnitudes of concentration and osmotic pressure of clay are typical examples of all the complex types of soils investigated. In the simple types of soils, however, as typified by quartz sand, the corresponding depression of .070°C indicates a concentration of only 2121 p. p. m. and an osmotic pressure of 0.800 atmospheres.

On the other hand, the concentration that the depression of the freezing point of all the soils represents at the high moisture content, is comparatively low, averaging about 600 p. p. m. for the majority of the complex soils and about 300 p. p. m. for the simple soils, with an osmotic pressure of .350 and .150 atmospheres, respectively.

A further examination of Table 2 also reveals the remarkable fact that the lowering of the freezing point increases in all the soils, with the exception of quartz sand, at a far greater rate than the percentage of water decreases. In other words, the ratio of the lowering of the freezing point and of the water content are not inversely proportional, (approximately), to each other as might be expected, except only in quartz sand. Thus, clay at 36.5% of moisture gave a depression of .034°C, and at 18.80%, .955°C, the ratio of the percentage of water at the two moisture contents is only 1.94, while that of the depression of the freezing point is 27.11. A sandy loam, which at 21.53% of water gave a depression of .020°C, and at 8.30%, .450°C, shows a ratio of 2.35 in percentage of water to 22.5 in the lowering of the freezing point. In the case of quartz sand, however, the ratio of the depression is directly inversely proportional to the water content. Thus, at 1.5% of water content the depression is .070°C and at 15% it is .007°C, the inverse ratio, therefore, being 10 to 10, respectively.

Apparently, the quartz sand yields different results from all the other types of soil and its data can be mathematically expressed by the simple equation M.D. = K. where K is a resultant constant, M is the percentage of moisture content and D, the observed depression of the freezing point. The following table serves to show how close the data of the quartz sand follow the above formula:

Table 3. Lowering of the Freezing Point of Quartz Sand at Various Moisture Contents.

Percentage of moisture.	Observed lowering of the freezing point.	Constant K.
1.5	.070	.105
3.7	.026	.0962
7.5	.012	.0920
15.0	.007	.105

The last column to the right contains the value or constant obtained by multiplying the percentage of moisture by the observed lowering of the freezing point. It will be noted that the constant K is practically the same at all moisture contents, which goes to prove that the data of the quartz sand follow the foregoing mathematical formula remarkably close.

The same constant is obtained even when the quartz sand is treated with a salt solution and allowed to dry and then determining its depression at different moisture contents.

The question now rises, do the results of the other types of soil also follow some mathematical law, i. e., are they expressable mathematically? In order to obtain definite data upon this point the lowering of the freezing point of a large number of soils was determined at various moisture contents. The procedure consisted of allowing the soils to become air dry and then adding different quantities of water to the same amount of soil, allowing the mixture to stand in a moist atmosphere at room temperature for about 24 hours and then determining its lowering of the freezing point. The moisture content varied from very low to very high. Great precaution was taken to moisten the whole mass of each sample very uniformly. Several types of soil were used for this study, but in Table 4 the results of only a sandy loam, humus loam, silt loam, and clay are presented, which suffice to illustrate the general principle. These results are graphically illustrated by Figure 2.

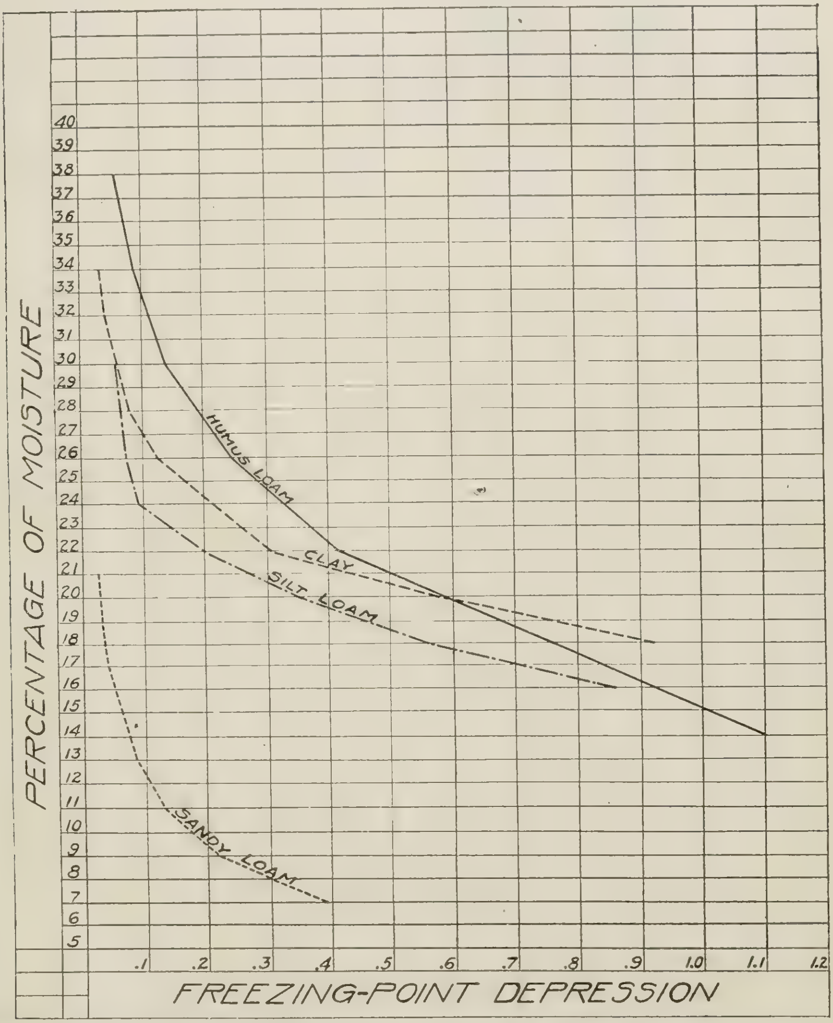

Fig. 2. Curves showing the increase in the lowering of the freezing point of soil with the decrease in moisture content.

Table 4. Lowering of the Freezing Point of Various Types of Soil at Different Moisture Contents.

Clay.			Silt Loam.		
Percentage of moisture.	Observed lowering of the freezing point.	Calculated lowering of the freezing point.	Percentage of moisture.	Observed lowering of the freezing point.	Calculated lowering of the freezing point.
18	.922		16	.860	
20	.580	.6242	18	.560	.6880
22	.307	.3916	20	.350	.4480
24	.212	.2078	22	.200	.2800
26	.127	.1435	24	.095	.1600
28	.082	.0859	26	.076	.0760
30	.062	.0555	28	.071	.0608
32	.042	.0419	30	.060	.0568
34	.034	.284	....	....	....
Humus Loam.			**Sandy Loam.**		
14	1.200	....	7.0	.390	....
18	.760	.7888	9.0	.220	.2925
22	.420	.4995	11.0	.130	.1650
26	.245	.2761	13.0	.087	.0975
30	.140	.1610	15.0	.065	.0642
34	.089	.0920	17.0	.040	.0487
38	.0585	.0585	19.0	.030	.0300
....	....	....	21.0	.025	.0225

The lowering of the freezing point at the different moisture contents is shown in the second column of each soil. These results also follow a mathematical law and indeed the geometric progression law, i. e., the lowering of the freezing increases in a geometric progression, while the percentage of water decreases in an arithmetic progression. The agreement between the observed and calculated values of the lowering of the freezing point is remarkably close,—considering the nature of the soil medium—as shown by the last two columns of each soil. The calculated values were obtained by dividing one of the observed depressions by the one preceding and multiplying the various lowerings of the freezing point by the ratio thus obtained. Since the depressions at the higher moisture content are considered to be the most accurate they were used for obtaining the ratio or constant. Probably it would have been permissible to take an average of all the ratios between the different values of the depression and in which case the calculated values would be much closer to the observed values. If the results then follow the geometric progression law they are expressable by the equation $D = AR^{n-1}$, where D is the depression of the freezing point, A the first depression, R the ratio of any depression (except the first) to the preceding one, and n the number of the depression. According to this formula if the lowering of the freezing of a soil is determined at two different moisture contents it can be calculated at any other moisture content.

The main facts brought out by the investigation thus far may be summarized then, as follows: At low moisture content the lowering of the freezing is extraordinarily high and very different for the various types of soil, being lowest in the sandy types and highest in the clay types; at high moisture content, however, the lowering of the freezing point is relatively very low and only slightly different for the diverse classes of soil; in all the different soils with the exception of quartz sand, the depression of the freezing point increases in a geometric progression as the percentage of moisture decreases in an arithmetic progression; in the case of quartz, however, the lowering of the freezing point increases directly as the moisture content decreases; the magnitude of concentration and osmotic pressure that the lowerings of the freezing point represent at the low moisture content, are tremendously high, especially in the complex types of soil, but at the high moisture content, they are comparatively very small.

It will at once be admitted, therefore, that these results are extremely unusual and do not harmonize with the present views concerning the soil solution. It is almost universally believed, for instance, that the soil solution is very dilute, and according to a theory advanced by Whitney and Cameron, (10), many years ago, the soil solution is not only very dilute, but also, its magnitude of concentration tends to remain constant and to be the same for practically all soils, since it tends to be saturated or in equilibrium with the mineral constituents of the soil. They based their theory upon the assumption that the mineral substances comprising the soil are complex salts with slight solubilities in water, and consequently, only small amounts of them would be required to go into solution to form a saturated solution. Since the solution is saturated in respect to the mineral constituents of the soil, the addition of a soluble salt, such as KCl, may not increase the concentration but would force back the disociation of the corresponding ions and thus maintain a constant concentration of solution.

Since the discovery of the phenomena of absorption and adsorption of salts by soils it has been suggested, especially by Schloesing, and at present very widely believed, that these properties control or regulate the concentration of salts in solution and that the concentration of the solution of any given soil tends to remain practically constant. This view is well expressed in a recent paper by Bogue, (11). To quote: "But, the concentration of the salts in the soil solution tends to remain practically constant for any given soil. Thus, for example, if the concentration of potassium in the soil moisture should be lessened by the leaching of heavy rains, or the taking up of potassium by the plants, or by any other cause, this concentration would quickly be re-established by the soil giving up of its absorbed potassium until the constant was again reached. Or, if on the other hand, the concentration of potassium in the soil solution should be increased as by the application of a soluble fertilizer, or by evaporation of the soil moisture, the constant would be restored by the absorption of the excess potassium by the soil."

The foregoing results on the lowering of the freezing point, as well as other data subsequently to be presented, diametrically oppose the above theories. Contrary to both these theories, the concentration of the soil solution as indicated by the lowering of the freezing point, does not remain constant but varies tremendously, and indeed increases greatly with the decrease in moisture content, so that at a low water content the magnitude of the concentration is very great. Furthermore, the magnitude of concentration at a low moisture content is not only not the same for the various types of soil, but it is far greater in those classes which would be expected to possess the greatest absorbtive power.

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(10) Bul. 22, Bureau of Soils, U. S. Dept. of Agr., 1903.
(11) Jour. Phys. Chem., 19, 665, 1915.

Hence, if either one or both of the above theories are correct, then the foregoing results on the lowering of the freezing point do not represent actual concentration of solution, but they are influenced by some physical force. One of the physical factors which might produce such results, it was thought, is the pressure with which the water films are held by the soil grains. It is well known, for example, that pressure lowers the freezing point of water to the extent as shown by the data in Table 5.

Table 5. Effect of Pressure on the Freezing Point of Water.

Pressure in Atmospheres.	Freezing Point of Water Lowered.
138.888	1.0°C
277.777	2.0
416.666	3.0
555.550	4.0
694.440	5.0
13,000.000	18-20

It was reasoned that at the low moisture content the pressure of the water films would be greater than at the high moisture content and consequently the lowering of the freezing point would be greater in the former than in the latter.

A critical theoretical examination of this hypothesis, however, has failed to show that the pressure is the probable cause of the results noted. Furthermore, all direct and indirect evidences point overwhelmingly against it. Some of the evidences against it may be mentioned the following: (1). The rate of increase of the lowering of the freezing point with the decease in moisture content, is practically the same from the lowest to the highest moisture content. (2). The washed quartz sand which would not be expected to contain a solution of high concentration gives a depression of only .070°C at 1.5% moisture content or almost at the point of dryness, while clay, which would be expected to possess a very highly concentrated solution, gives a lowering of the freezing point of .955°C at 18.80% moisture. The clay, at a high moisture content where the pressure of the water films would be reduced to minimum, gives a freezing-point depression many times greater than that of the quartz sand at the point of dryness. (3). The water which is adsorbed or condensed on the surfaces of the soil particles on account of the great pressure probably resulting from the adhesive forces, is conceived to be removed from the liquid phase and becomes solid like water of crystallization and probably takes no part in the freezing, as will subsequently be discussed.

There appears to be no other physical factor known to affect the freezing point of water. A number of minor possibilities have been suggested, but after a careful examination and consideration they all have been discarded.

The conclusion seems to be inevitable, therefore, that the great lowerings of the freezing point noted are caused by and represent actual concentration of solution and therefore contradict the foregoing theories regarding the constancy and magnitude of concentration of the soil solution.

No definite and proved theory can be offered to explain this apparent great increase in concentration of the soil solution with decrease in moisture content. The following hypothesis, however, would appear to explain the phenomena and is here tentatively offered.

It is assumed that the soil solution contains salts or their ions, produced by the reaction of the dissolved components of the soil minerals, hydrolysis of the minerals, application of fertilizers, decomposition of organic matter, etc. These salts have as a rule a high solubility and would require a large amount of them to form a saturated solution. They are formed rather slowly and since the frequent rains, especially in the humid regions, tend to leach them away only a relatively small amount of them is present at a time. At a high moisture content these salts are diluted and the lowering of the freezing is small. As the moisture content, however, is reduced they are concentrated and the lowering of the freezing point becomes greater. Since these salts are present only in relatively small amounts, they do not form a saturated solution, or at least many of them do not.

A critical consideration of the character of the soil system and a thorough examination of the available general data of the soil solution, as obtained through soil water extracts, drainage water, etc., lend considerable support to the above hypothesis.

A consideration of the soil mass shows that it is a heterogeneous mixture composed of solids, gases, and a liquid, and inhabited by living organisms. The solid portion, in normal soils, is composed of mineral debris and organic matter, from rock and from plant and animal degradation and decomposition, respectively. Both of these classes of solid matter are guadually reduced to the liquid state. The organic matter, for instance, mainly through the activities of the living organisms, is rendered soluble and many organic and inorganic compounds are formed, including the nitrates, humic acids, etc. The nitrates may exist as $NaNO_3$, $Ca(NO_3)_2$, $Mg(NO_3)_2$, etc., depending upon the preponderance of the base present to unite with the acid. These salts have a very high solubility constant and to form a saturated solution a very great amount of them is required. Thus, to form a saturated solution at 20°C would require 83.7 grams of $NaNO_3$, 31.6 gm. of $Mg(NO_3)_2$, and 54.8 gm. of $Ca(NO_3)_2$, in 100 gm. of water. It is very doubtful, therefore, whether a normal soil and especially under humid conditions ever possesses a saturated solution in respect to these salts. Assuming, therefore, that there is a certain amount of nitrate salts in the soil solution then it naturally follows that at a high moisture content it is diluted, and, as the percentge of water is reduced, it becomes more concentrated; hence, the lowering of the freezing point would tend to increase from the high to the low water content.

The dissolution of the mineral matter is accomplished by the solvent action of water aided by the foreign substances that it might be charged with, such as acids, bases, and salts. The soil minerals, however, are as a rule but slightly soluble and their rate of solution is generally very slow, so slow indeed that it requires months and even years, at least with certain minerals, to form a saturated solution. Thus, Cameron and Bell, (12), found that by placing powdered glass, orthoclase, albite, and some Podunk fine sandy loam with water in paraffin cylinders and rotating them in a constant temperature bath at 27°C for about 9 weeks, equilibrium was not yet attained. Many if not all of the common soil forming materials, however, undergo hydrolysis and thereby increase their degree and rate of solubility. Their solubility may be further increased by the addition of soluble compounds yielding non-common ions, or by the reacting with some of the minerals to form new compounds, or by the dissolved components of the different minerals acting upon one another to form new compounds.

Through these processes of hydrolysis, chemical reaction between applied salt and soil mineral, and the reaction of the dissolved components of the different minerals, probably there are formed in the soil solution, salts of high solubility.

In the analysis of soil water extracts, drainage waters, etc., there are found, besides the NO_3 acid radical, the acid radicals HPO_4, SO_4, HCO_3, Cl, SiO_3, and the base radicals, Na, Mg, Ca, K, etc. These acids and bases could well combine to form such compounds, for instance, as $CaH_4(PO_4)_2$, Na_2HPO_4, K_2HPO_4, $NaHCO_3$, $Mg(HCO_3)_2$, $CaSO_4$, Na_2SO_4, NaCl, KCl, $CaCl_2$, etc.

That such compounds are formed and do exist in the soil solution to a more or less extent, can hardly be doubted. Both direct and indirect evidences strongly support the assumption. For instance, in those regions where the rainfall is small and the amount of leaching is consequently slight, such as in the arid regions, there is an accumulation of soluble salts near or at the surface soil, transported from below by the evaporation of the soil water. Such an accumulation of salts is designated as alkali conditions. Such alkali conditions would occur even in the humid regions were it not for the excessive and frequent rains which tend to wash away these soluble salts and thus prevent their accumulation. The soluble salts found wherever alkali conditions exist vary in number and composition, but in most arid countries the chlorides, sulphates, and carbonates of sodium, calcium, and magnesium, predominate. Several other salts are generally found but not in large amounts. In humid regions there are many cases known where seemingly alkali conditions exist. Cameron, (11) reports that a soil in Maryland near the Maryland Agricultural College contained the following salts in large quantities: $NaNO_3$, KNO_3, $Mg(NO_3)_2$, $Ca(NO_3)_2$,

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(12) Bul. 30, Bureau of Soils, U. S. Dept. of Agr., 1905.
(11) Bul. 17, Bureau of Soils, U. S. Dept. of Agr., p. 36, 1901.

$CaSO_4$, $CaCl_2$, etc. Stevenson and Brown, (12), have found that there are alkali spots in certain areas in Iowa which are composed mainly of $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, Na_2SO_4, $NaNO_3$, etc.

In a very extensive investigation King, (13), found that the amount of water-soluble salts in soils was high, and varied with the type of soil, the fertility, or manurial treatment it had received, etc. The table below shows a typical example as to the magnitude of the salts recovered in the water extracts by the conventional method. These salts are composed of K, Ca, Mg, NO_3, HPO_4, SO_4, HCO_3, Cl, and SO_2.

Table 6. Total Salts Recovered from the Surface Foot of Eight Soil Types, 1903.

	Pounds per million of dry soil.	Pounds per acre of dry soil.
Norfolk Sandy Soil	182.02	654.4
Selma Silt Loam	226.94	788.6
Norfolk Sand	167.22	599.7
Sassafras Sandy Loam	199.70	682.3
Hagerstown Clay Loam	590.3	1,670.0
Hagerstown Loam	532.15	1,532.0
Janesville Loam	468.19	1,330.00
Miami Loam	419.23	1,301.00

It will be readily seen that the quantity of soluble salts dissolved into the water extract is really high. Of course the investigation does not show in what form these compounds exist in the soil, whether in solution or in solid form, but readily soluble. If these acids and bases, however, unite to form salts which have a high solubility, there is no reason to doubt why they should not be in solution.

In performing leaching experiments various investigators have found that the first portion of the water passing through the dry soil always contains a far greater concentration than the subsequent leachings. The subsequent leachings finally reach a low degree of concentration which tends to remain constant. The higher concentration of salts in the first washings is attributed by some investigators to the decrease in absorbtive power of the soil for the salts, due to the process of drying. It could be equally attributed to the presence of readily soluble salts.

Furthermore, that salts of high solubility may exist in the soil solution is further confirmed by the reaction that is conceived to take place between the soil and a soluble salt added. Thus, $Alx\ Fex\ Mgx\ Nax\ Ca(SiO_3)x\ (H_2O)x + 2KCl = Alx\ Fex\ Mgx\ Nax\ K_2(SiO_3)x\ (H_2O) + CaCl_2$. The $CaCl_2$ is assumed to be in solution.

The evidences, therefore, of the existence of salts of high solubility in the soil solution are very strong. The solubilities of some of the salts that are likely to occur in the soil solution are shown in Table 6.

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(12) Bul. 157, Ia. Agr. Expt. Sta., 1915.

(13) Bul. 26, Bureau of Soils, U. S. Dept. of Agr., p. 67, 1905.

Table 7. Solubility of Various Salts at 20° C.

Name of Salt.	Grams of Salt dissolved in 100 gm. of water.
$NaNO_3$	83.7
KNO_3	31.6
$Ca(NO_3)_2$	54.8(19)
$Mg(NO_3)_2$	42.33(19)
KCl	34.07
$NaCl$	35.82
$CaCl_2$	74.00
K^2SO_4	11.11
$CaSO_4$	....
$MgSO_4$	36.2
$Ca(HCO_3)_2$	....
$Mg(HCO_3)_2$	....
$NaHCO_3$	9.60
$CaH_4(PO_4)_2$	....
$(NH_4)^2SO_4$	75.4

(19) at 18° C

Since the formation of these salts is comparatively slow and their accumulation to any extent is prevented by the excessive and frequent rains in the humid regions, their amount in the soil solution is relatively small and does not form a saturated solution, probably, not even at a low moisture content. Those of course that form a saturated solution are separated in the solid phase. At a high moisture content, therefore, these salts are diluted and would cause only a small lowering of the freezing point, but as the water content is reduced they become more concentrated and they would cause a correspondingly greater lowering of the freezing point. That is exactly what the experimental results show. Hence, the experimental data agree almost perfectly with the hypothesis.

The foregoing hypothesis, however, does not explain why the lowering of the freezing point increases in a geometric progression while the moisture content decreases in an arithmetic progression, and not follow a direct invere proportionality ratio, (approximately), as might be expected.

It must be stated, however, that also for this phenomenon, no definite and proved explanation can be offered. The following hypothesis, however, would seem worth considering.

It is assumed that a portion of the water found in the soil is inactive or unavailable and does not take part in dissolving the salts in the soil. How this portion of the water is rendered inactive and in what form it exists, cannot be asserted with certainty. There are two possible ways in which it might exist: (1), as loosely chemically combined water, and (2), as adsorbed water. In the first case the water might react with some of the components of the soil to form hydrolysed substances or hydrates. There is a great amount of evidence which goes to bear out this view. It is suggested by Muntz and Gaudechon, (14), that a part of the heat generated upon moistening dry soils is probably due to chemical combination between the water and some soil components. Clays, for instance, are believed to possess in the highest degree the power to form substances of hydration. Dry hydrogels upon rewetting, are believed to enter into chemical combination with water in order to resume their colloidal state.

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(14) Ann. Sci. Agron. (3), 4, 393-443, 1909.

If the water is physically adsorbed it is conceived that it is removed from the liquid phase and becomes practically solid like water of crystallization. It becomes then inactive or inoperative in the same manner as when a solute is adsorbed.

In which form of the above the inactive water exists, cannot be stated definitely. It is very probable that it exists in both forms. But in whichever form it might exist, the assumption that it is inactive or unavailable to dissolve the salts tends to explain the results, at least partially. Thus, for example, assuming that a clay soil adsorbs or combines chemically with 15% of water, and that this clay at 36% moisture causes a lowering of the freezing point of 0.034°C, and at 18%, .955°C, then at the former moisture content there is 21% of water available to dissolve the salts in the soil, while in the latter case there is only 3% available for the same purpose. It would be natural, therefore, that the depression of the freezing point would be many times greater at the low percentage of moisture content than at the high, than would be expected from the difference of the total moisture content, just as the experimental data really indicate.

The foregoing hypothesis, therefore, would tend to explain, at least partially, why the lowering of the freezing point of the various types of soil with the exception of quartz sand and possibly some extreme types of sandy soil, should increase in a geometric progression while the percentage of water decreases in an arithmetic progression. It would also tend to explain why the lowering of the freezing point of quartz sand should increase inversely proportional with the water content, which would tend to indicate that quartz sand causes very little, if any, of the water to become inactive. That the latter fact might be so is further shown by the solidification which can be induced when the moisture content is only about 0.7%, practically at the air dry state.

Mention has already been made that in conducting a preliminary series of tests to ascertain how close the lowering of the freezing point of a soil sample could be duplicated it was found that at a high moisture content the duplicate readings would agree almost perfectly with one another for all types of soil but at a low moisture content the duplicate readings would agree with one another very close only with some soils, such as the quartz sand, kaolin, burned silicic acid, etc., but with other soils, such as the clay, loam, etc., the duplicate readings would vary appreciably, and indeed the first depression would be always greater than the second. This latter phenomenon was made of further special study by determining the lowering of the freezing point of a number of types of soil at low moisture content at successive freezings. The freezing process consisted of either allowing the soil sample to freeze at its proper freezing point and then thawing it by holding the tube containing the soil in the hand, or allowing the temperature of the soil to fall 3 or 4°C after it had frozen and then thawing it as before. Some of the results thus obtained are shown in Table 8. The magnitude of the decrease of the depression due to the successive freezings is not comparable either within the same soil or in different soil types, because the length of time and degree of freezing or super-freezing were not the same neither within the same soil nor in the different soils. These results are intended to show only that successive freezings tend to decrease the lowering of the freezing point of some soils and not of others.

Table 9. Decrease of the Lowering of the Freezing Point with Successive Freezings.

Quartz sand.			Sandy loam.		
Percentage of moisture.	Number of times frozen.	Lowering of the freezing point.	Percentage of moisture.	Number of times frozen.	Lowering of the freezing point.
1.5	1	.075	7.10	1	.520
	2	.077		2	.410
	3	.076		3	.400
	4	.075		4	.400
	5	.073			
Clyde Loam.			Clay.		
22	1	.900	17.00	1	1.245
	2	.700		2	0.705
	3	.620		3	.555
	4	.560		4	.550
	5	.555		5	.540
Clay.			Burned Silic Acid.		
18.80	1	.960	89.66	1	.535
	2	.855		2	.520
	3	.665		3	.525
	4	.600		4	.522
Kaolin.					
13.42	1	1.155			
	2	1.115			
	3	1.110			
	4	1.110			

It will be noticed that the lowering of the freezing point of quartz sand, burned silicic acid, and kaolin remains practically the same with successive freezings, but that of sandy loam, Clyde loam, and the two clays, becomes less with each repeated freezing and that the degree of diminution is very considerable, amounting in the clay soils to about 50% and in the sandy soil about 20%. This amount of decrease in depression, however, in the clays, loams, etc., would not have been so great had these soils not been cooled 3 or 4°C after they were frozen and kept at that low temperature for some length of time. The decrease has about reached its limit with all these soils as further freezings did not cause any important variations.

The question now is what causes this diminution of the lowering of the freezing point with successive freezings in the case of the agricultural soils and why a similar diminution does not occur in the more artificial substances. It must be admitted, however, that for this phenomenon also, no definite and proved explanation can be offered. The following suggestions, however, seems to deserve and warrant consideration.

It was first thought that the soil solution at the low moisture might have reached its saturation point in concentration and as it cooled, salts separated, for the solubility of the salts diminishes with falling temperature, and thus the solution became less concentrated. This hypothesis, however, would not explain the continued decrease in depression with repeated freezings, for if the soil solution were concentrated to the saturation point at the low moisture content all the excess of salts should separate the first time that it is cooled below O°C, and inasmuch as probably not all of the separated salts would go again into solution upon thawing—owing to the short length of time—the concentration of the solution and hence the lowering of the freezing point should remain more or less stationary. Hence, this hypothesis fails to explain the results.

If it is true that the soil adsorbs water and that this adsorbed water is removed from the liquid phase and becomes almost solid like water of crystallization and it no longer acts as a solvent of the salts in the soil, then the foregoing phenomenon on the diminution of the depression with repeated freezings might be explained under the following hypothesis: The adsorption of the water is due, at least in part, to the colloids in the soil. Upon freezing, these colloids coagulate and the bonds uniting them with the water break and the adsorbed water becomes liberated. This liberated adsorbed water becomes available and goes to dilute the original solution and thereby decreases the lowering of the freezing point. Thus, for instance, if there were only 5% of available moisture before the first freezing was made, there is probably 6% at the end of the first freezing, 7% at the end of the second freezing, and so on, until probably all or most of the colloids are coagulated. The coagulation is not complete in the first freezing but the greatest amount takes place in the first freezing and then smaller amounts in the successive freezings.

This hypothesis seems to find a large amount of confirmation from both direct and indirect evidences. It is now generally believed that there are present in soils both hydrosols and hydrogels consist of organic substances, the humus compounds, and inorganic substances, the hydrates of alumina, iron, manganese, hydrated silica, the zeolitic silicates, etc., that the hydrosols are continually being produced in the soils by physical action such as that of the water on clay, or by chemical changes such as the decomposition of silicates; and, that there are in nature various agencies such as changes in temperature, concentration of solution, etc., by which hydrosols are changed to hydrogels, and vice versa. Changes in temperature are known to produce especially very marked effects upon these colloids. Both heating and freezing have been found to cause coagulation of the hydrosols and hydrogels and that this coagulation is accompanied by a decrease in the absorbtive power. It has been abundantly proved, for example, that when clay is heated its absorbtive power for water is greatly diminished.

This hypothesis, therefore, would seem to explain very well the diminution of the depression of the freezing point of the agricultural soils at low moisture content with repeated freezings. It would seem also to suggest that the artificial substances, such as the quartz sand, burned silicic acid, and kaolin, either do not contain colloidal material, or if they do, it is not coagulable.

At the high moisture content coagulation of the colloids of the agricultural soils should also take place, but since the amount of water present is high, and the solution is relatively very dilute, the amount of water that is released upon coagulation is too small to make any noticeable effect upon the depression.

In late years a great amount of work has been done upon the effect of steam heat on the solubility of soil constituents. Especially important and valuable are the investigations of Russel and Hutcheson, (15), and Lyon and Bizzel, (16), upon the subject. These investigators, as well as others subsequently, found that in general, steam heat increased the ammonia content as well as the water-soluble inorganic matter.

In order to show the applicability of the freezing point method on this subject and also to ascertain to what degree the steam heat increases the concentration of the solution, the lowering of the freezing point of a few types of soil steam heated, was determined. The general procedure consisted of taking soils from the field, bringing them up to a high moisture content, and then dividing each soil into two parts, one part was used as a check and the other part was steam heated in an autoclave for about 3 hours at a pressure of 15 atmospheres. After steaming, the moisture content was brought up to the original and the lowering of the freezing point was determined. The following table contains the depression of the freezing point of the unsteamed and steamed portions of each soil. Only a very limited number of soil types was employed because it was desired to show mainly the applicability of the method on the subject.

Table 9. Effect of Steam Heat on the Lowering of the Freezing Point of Soils.

Name of Soil.	Lowering of the Freezing Point.
Sandy loam unsteamed	.020
Sandy loam steamed	.035
Clay unsteamed	.030
Clay steamed	.045
Clyde loam unsteamed	.040
Clyde loam steamed	.115
Peat unsteamed	.015
Peat steamed	.065

It will be at once seen that steam heat increased the lowering of the freezing, and consequently the concentration, in every soil, but the magnitude of the increase is by far greater in those soils in which the organic matter is very high or predominates, than in the mineral soils. Apparently steam heat causes a greater amount of material to go into solution in the former than in the latter classes of soil.

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(15) Jour. Agr. Sci. 2, 411, 1908.
(16) New York Cornell Sta., Bul. 275, 1910.

Besides employing the freezing point method to determine the concentration of the soil solution in the soil at various moisture contents, it can also be used, of course, to measure the salt content of alkali soils. Through the kindness of Dr. F. S. Harris of the Utah Agricultural College we were able to secure soil samples of alkali, irrigated and non-irrigated soils. All these soils could be classed as heavy sandy loams. The lowering of the freezing point obtained from these soils is shown in the following table.

Table 10. Lowering of the Freezing Point of Alkali, Irrigated, and Non-irrigated Soils of the Arid Region.

Name of Soil.	Percentage of moisture.	Lowering of the Freezing Point.
Alkali	27.23	1.950°C
Non-irrigated	16.36	.320
Irrigated	17.72	.210

It will be readily seen that the depression and hence the concentration of salts in solution are very great in the alkali soil, even at such high moisture content, almost at the saturation point; at a low moisture content the depression was so great that it could not be read on the scale of the thermometer. The depression of the non-irrigated soil is greater than that of the irrigated even though the moisture content of the latter is greater than that of the former. The magnitude of the depression in both cases, however, is small due to the high water content present.

In conclusion, then, it must be stated that if it is to be accepted that the lowering of the freezing point of soils at the different moisture contents represents actual concentration of solution, then many extremely important and far-reaching consequences follow. (1). The soil solution is not under all conditions dilute as is generally believed. It is dilute only at the high moisture content but at a low moisture content it is tremendously concentrated and its concentration can be increased by the application of soluble salts. (2). The concentration of the soil solution does not remain constant but varies tremendously with the moisture content and the amount of soluble salts applied. (3). The solution of normal soils in humid regions may never reach a saturation point, at least with most salts. (4). The magniture of concentration of solution is not the same for all soils, but varies greatly with the different soils. (5). The absorbtive power of the soil does not seem to influence at all the concentration of the solution; those soils known to possess the highest absorbtive power generally contain a very high concentration of solution and those that have a low absorbtive power possess a low concentration of solution. Hence, the two prevailing theories regarding the concentration of the soil solution are diametrically opposed by the results of this investigation.

Furthermore, the acceptance that the lowering of the freezing point at the low moisture contents represents actual concentration of solution throws a new and important light on the subject of the wilting coefficient of plants. The wilting of plants has heretofore been generally attributed to their inability to take up the water which is held by the soil with a great attractive force. While this explanation is undoubtedly correct and especially if it is true that some of the water is loosely chemically combined or physically adsorbed and consequently removed from the liquid phase, yet if the great depression of the freezing point at the low moisture content represents concentration of solution, then the wilting of plants must be also influenced by plasmalytic phenomena. As already seen, the calculated concentration amounts in some cases to over 28,000 p. p. m., which is equivalent to an osmotic pressure of over 12 atmospheres. At a still lower moisture content these magnitudes would be far greater. When it is considered that the osmotic pressure of the cell sap of such common agricultural plants as wheat, barley, oats, corn, generally amounts to only about 5 atmospheres under humid conditions then the possibility of the wilting of plants in some soils at least being partly due to the plasmolytic phenomena, becomes greatly strengthened. Again, the best standard nutrient solutions contain an osmotic pressure of only between 1.50 and 1.75 atmospheres. Knops standard nutrient solution and the more recent one proposed by Shive, (17), contain an osmotic pressure of 2.75 and 1.5 atmospheres, respectively.

It would seem very possible, therefore, that in some soils at least, especially in the complex types where the depression of the freezing point is greatest, the concentration of the .solution probably plays a very important part in the wilting of plants.

Again, if the concentration of the soil solution varies tremendously with the moisture content, then it becomes at once obvious that the centifuge and paraffin oil methods can give some information concerning the concentration of the soil solution only at the moisture content at which the extraction can be made. Even at that moisture content, however, the concentration of the extracted water is only approximately close to the total concentration of the entire moisture in the soil, if the theoretical principles already discussed (p. 6) are correct.

Finally, it must be stated that the freezing point method with further development promises of furnishing a quantitative comparison of the soluble salt content in different soils and thereby give an idea as to their degree of fertility. In its present stage it can only compare the concentration or salt content of the soil solution at different moisture contents of the same soil, and between very extreme types of soil. The moisture content seems to be the controlling factor and the development of the method towards being employed to compare quantitatively the salt content and probably the fertility of different soils, lies in standardizing the moisture content, and this phase of the work is now under investigation.

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(17) Plant World, 1915.

Effect of Application of Soluble Salts Upon the Concentration of the Soil Solution in the Soil.

Our present knowledge concerning the effect of application of soluble salts upon the concentration of the soil solution in the soil is extremely unsatisfactory. A great amount of experimental work has been done upon the subject but the conclusions drawn therefrom are not at all concordant. This is undoubtedly due to the fact that there has been no method of attacking the problem directly and consequently the studies had to be conducted indirectly. As a result of this difficulty many of the present views concerning the effect of application of soluble salts upon the concentration of the soil solution in the soil have been deduced from *a priori* consideration from certain physical laws of solutions and physical properties of soils. According to the theory advanced many years ago by Whitney and Cameron, (18), the application of soluble salts such as KCl would probably not increase the concentration of the soil solution. They based their theory upon the law of equilibrium of solutions. Their studies with water extracts led them to believe that the soil solution is saturated or nearly saturated in respect to the soil constituents, and the application of such soluble salts with which the solution is already saturated would merely force back the dissociation and thus re-establish equilibrium. The concentration of the soil solution, therefore, tends to remain constant.

According to the absorption-adsorption theory the concentration of the soil solution may not be increased by the application of soluble salts. It is maintained that these phenomena of absorption-adsorption tend to maintain a practically constant concentration of solution for any given soil. Indeed, it is asserted that it is these properties of the soil which prevent the soil solution from becoming too concentrated either upon withdrawal of moisture or application of salts to the soil,

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(18) Bul. 22, Bureau of Soils, U. S. Dept. of Agr., 1903.

	n/100 KCl					n/100 K_2SO_4					n/100 $MgSO_4$					n/100 $(NH_4)_2 SO_4$					n/100 $Ca(NO_3)_2$				
	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.
	°C	°C	°C			°C	°C	°C			°C	°C	°C			°C	°C	°C			°C	°C	°C		
Purified Quartz	.370	.370	0	0	100.	.250	.248	.002	0.80	99.20	.130	.130	0	0	100.0	.243	.243	0	0	100.0	.180	.178	.002	1.11	98.89
Unpurified Quartz	.370	.360	.010	2.70	97.30	.250	.240	.010	4.00	96.00	.130	.128	.002	1.54	98.46	.243	.243	0	0	100.0	.180	.170	.010	5.56	94.44
Sandy loam	.370	.320	.050	13.51	86.49	.250	.155	.095	38.00	62.00	.130	.130	0	0	100.0	.243	.160	.083	34.16	65.84	.180	.180	0	0	100.0
Silt loam	.370	.282	.088	23.78	76.22	.250	.112	.138	55.20	44.80	.130	.112	.018	13.85	86.15	.243	.122	.121	49.79	50.21	.180	.177	.003	1.67	98.33
Silt loam	.370	.285	.085	22.97	77.03	.250	.105	.145	58.00	42.00	.130	.115	.015	11.54	88.46	.243	.125	.118	48.56	51.44	.180	.175	.005	2.78	97.22
Clyde loam	.370	.262	.108	29.19	70.81	.250	.050	.200	80.00	20.00	.130	.070	.060	46.15	53.85	.243	.090	.153	62.96	37.04	.180	.152	.028	15.56	84.44
Red Clay	.370	.275	.095	25.68	74.32	.250	.105	.145	58.00	42.00	.130	.105	.025	19.23	80.77	.243	.130	.113	46.50	53.50	.180	.180	0	0	100.0
Gray Clay	.370	.295	.075	20.27	79.73	.250	.055	.195	78.00	22.00	.130	.055	.075	57.70	42.30	.243	.160	.083	34.16	65.84	.180	.175	.005	2.78	97.22
Peat	.370	.305	.065	17.57	82.43	.250	.180	.070	28.00	72.00	.130	.120	.010	7.69	92.31	.243	.183	.060	24.69	75.31	.180	.110	.070	38.89	61.11
Kaolin	.370	.340	.030	8.11	91.89	.250	.205	.045	18.00	82.00	.130	.130	0	0	100.0	.243	.243	0	0	100.0	.180	.165	.015	8.33	91.67

	n/100NaNO₃					n/100K₂HPO₄					n/100CaH₄(PO₄)₂					n/100Na₂HPO₄				
	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.	Depression of Solution alone.	Depression of Solution with Soil.	Difference.	Percentage of change in Depression.	Percentage of Original Concentr. of Salt Solution Went to Concentrate Soil Solution.
	°C	°C	°C			°C	°C	°C			°C	°C	°C			°C	°C	°C		
Purified Quartz	.370	.368	.002	.054	99.95	.120	.117	.003	2.50	97.50	.070	.068	.002	2.86	97.14	.180	.177	.003	1.67	98.33
Unpurified Quartz	370	.360	.010	2.70	97.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sandy loam	.370	.325	.045	12.16	87.84	.120	0	.120	100.0	0	.070	.002	.068	97.14	2.86	.180	.003	.177	98.33	1.67
Silt loam	.370	.332	.038	10.27	89.73	.120	.002	.118	98.33	1.67	.070	.002	.068	97.14	2.86	.180	.025	.155	86.11	13.89
Silt loam	.370	.345	.025	6.76	93.24	.120	.005	.115	95.83	4.17	.070	0.0	.070	100.0	0	.....	.....	.....	.....	.....
Clyde loam	.370	.277	.093	25.14	74.86	.120	.007	.113	94.16	5.84	.070	0	.070	100.0	0	.180	.013	.167	92.78	7.22
Red Clay	.370	.333	.037	10.00	90.00	.120	.008	.112	93.33	6.67	.070	0	.070	100.0	0	.180	.010	.170	94.45	5 55
Gray Clay	.370	.330	.040	10.81	89.19	.120	0.0	.120	100.0	0	.070	0	.070	100.0	0	.180	.011	.169	93.88	6.12
Peat	.370	.275	.095	25.68	74.32	.120	.070	.050	41 67	58.33	.070	.025	.045	64.28	735 2	.180	.070	.110	61.11	38.89
Kaolin	.370	.340	.030	8.11	91.89	.120	.075	.045	37.50	62.50	.070	.055	.015	21.43	78.57	.180	.115	.065	36.11	63 89

which would be detrimental to the growth of plants. Through the absorption-adsorption phenomena, salts are given up to the soil solution when the latter becomes dilute, or salts are withdrawn from it when it becomes concentrated and thus a constant equilibrium is maintained.

Since it was found that by means of the freezing point method the concentration of the soil solution can be measured directly in the soil, it was at once suggested that this method might be used to study directly the effect of application of soluble salts upon the concentration of the soil solution in the soil. The results thus directly obtained ought to show definitely whether or not the concentration of the soil solution in the soil can be increased by application of soluble salts.

The procedure consisted of treating different types of soil with n / 100 solution of various salts, allowing them to stand in room temperature and saturated atmosphere for about 24 hours, and then determining the lowering of their freezing point. To each soil sample was added a sufficient amount of a solution to bring it up to a very high moisture content, thus eliminating some of the errors that occur at the low moisture content. For each treated sample there was always a check having the same percentage of moisture, but made up only of water. Great care was taken to mix each soil sample with the solution or water, very thoroughly. The results obtained are detailed in table 11,

Table 11. Effect of Application of Soluble Salts upon the Concentration of the Soil Solution in the Soil.

Before entering into the discussion of the foregoing data, an explanation as to their form of presentation is necessary. The first column to the left of each salt solution contains the lowering of the freezing point of the solution itself; the second column contains the lowering of the freezing point of soil treated with the solution, and, this lowering is entirely due to the solution applied, as the amount of depression due to the soil itself at that moisture content has been subtracted; the third column shows the difference in the depression of the solution before and after it is added to the soil; the fourth column contains the percentage of change in the depression that the salt solution suffered in the soil; and, the fifth column shows what percentage of the original concentration of the salt solution went to increase the concentration of the soil solution.

With this explanation, the above data showing the influence of application of soluble salts upon the concentration of the soil solution in the soil may now be considered. An examination of the figures in the fifth column of the various salt solutions shows many remarkable facts. Starting with the KCl solution it will be seen that from 70.81 to 100% of the concentration of the salt solution went to concentrate the soil solution. The concentration of the soil solution is increased greatest in quartz sand, kaolin, sandy loam, and peat, and least in humus loam.

Considering next the K_2SO_4 solution it will be seen that a much smaller percentage of the concentration of this salt solution went to increase the concentration of the soil solution of the various soils. With the exception of quartz sand and kaolin, where the increase is

99.2 and 78.0%, respectively, the increase in the other soil is comparatively small, amounting in the case of humus loam to only 20%, gray clay 22%, red clay 42%, etc. It is interesting to note that in the red clay the concentration is 20% greater than in the gray clay. Evidently, therefore, the influence of K_2SO_4 upon the concentration of the soil solution of the various soils is not as great as that of KCl.

The solution of $MgSO_4$ increased the concentration of the soil solutions of some soils quite appreciably, but in others only a very small amount. Thus, in the quartz sand, sandy loam, silt loams, kaolin, and peat the greatest part if not all of the original concentration of this salt solution went to concentrate their soil solutions but in gray clay, humus loam, and red clay, a smaller portion of the original concentration was used for the same purpose.

The $(NH_4)_2SO_4$ solution increased the concentration of the soil solution of the agricultural soils on the average much less than the $MgSO_4$ but considerably more than the K_2SO_4. It will be seen that in the quartz sand and kaolin fully the entire concentration of the salt solution was added to their solution, but in the other agricultural soils only about half of the original concentration was imparted to their soil solutions.

The increase in concentration of the soil solution of the various soils by the $Ca(NO_3)_2$ and $NaNO_3$ solutions is extremely interesting. It will be noted that in all the soils, with the exception of peat and humus loam, practically the entire concentration of these two salt solutions was added to their soil solutions and the percentage of the $Ca(NO_3)_2$ is appreciably greater than that of the $NaNO_3$. The failure of both clays to decrease at all the concentration of $Ca(NO_3)_2$ is of especial interest.

Of all the compounds used, the phosphates increased the concentration of the soil solution of the agricultural soils the least. Indeed, it will be seen that with the exception of quartz sand, peat, and kaolin, the concentration of the solution of the other soils was increased from 0.0 to only 8.78% of the original concentration of K_2HPO_4, $CaH_4(PO_4)$, and Na_2 HPO_4 solutions. Of the three solutions the last caused the greatest increase in the contentration which is only about 8%. Evidently these compounds have very little if any effect upon the concentration of the soil solution of most agricultural soils.

In order to ascertain whether greater concentrations than n / 100 of these phosphate compounds would increase the cencentration of the soil solution a normal solution of each was employed. The lowering of the freezing point of n / 1 Na_2HPO_4 solution, however, could not be determined on account of its saturation point and the consequent precipitation, and, therefore, no calculation could be made to what extent it influenced the concentration of the soil solution. The following table, therefore, contains only the results obtained with n / 1 solution of K_2HPO_4 and $CaH_4(PO_4)_2$ in red clay.

Table 12. Effect of Normal Solutions of $K_2H\ PO_4$ *and* $CaH_4\ (PO_4)_2$ *Upon the Concentration of the Soil Solution of Red Clay.*

Name of Solution.	Depression of solution alone.	Depression of solution with soil.	Difference.	Percentage change in depression of solution.	Percentage of concentration if original solution went to concentrage soil solution.
K_2HPO_4........	1.900	.275	1.625	85.5	14.5
$CaH_4(PO_4)_2$......	.630	.073	.557	88.4	11.6

These results show that by increasing the concentration to n/1 a greater percentage of the concentration goes to increase the concentration of the soil solution of the clay than when n/100 strength is used, but the amount of increase, however, is small in comparison with the strength of the salt solution used.

This part of the investigation goes to show, therefore, that the different compounds employed have an entirely different effect upon the concentration of the soil solution of the various types of soil. In the case of the neutral salts the soil solution was increased from 20 to 100% of their strength added, while in the case of the phosphate salts very little if any of their concentration was imparted to the soil solution of the agricultural soils.

The contention of the two theories already mentioned that the concentration of the soil solution tends to remain constant and is in equilibrium with the soil and that the application of soluble salts may not increase this concentration, are not entirely confirmed or borne out by the data of this investigation. The only compounds which do not seem to cause an increase in the concentration of the soil solution are the phosphates, and that is only in certain soils.

The question now is: How is this increase in concentration of the soil solution by the soluble salts brought about? And, what is the composition of the resulting soil solution?

As already stated the lowering of the freezing point indicates only total concentration, and it tells nothing of the reactions that might take place between the soil and solution, or of the composition of the resulting soil solution. To obtain an answer to the above question, or questions, therefore, it is necessary to resort to other means.

In the study of adsorption or fixation of salts by soils one of two methods is generally employed: (1), either to shake a certain amount of soil with an excess amount of solution, and analyse the supernatant liquid, or, (2), to pass through a column of soil, a salt solution and analyse the percolate. These studies have shown that in the case of neutral salts the amount of the base of the salt solution added is diminished and an equivalent or nearly equivalent amount of other bases are dissolved in the solution. Thus, if a soil is treated with a solution of KCl the amount of K in the resulting solution is diminished but is replaced by an almost equivalent amount of other bases such as Ca, Mg, etc., while the amount of Cl remains practically unchanged.

In explanation of this phenomenon two theories have been proposed. One is based upon a chemical reaction between the soil and solution with an exchange of bases, and the other is based upon a physical selective adsorption of the base of a salt with a resulting acid which dissolves an equivalent amount of the soil bases. In the first theory it is assumed that a neutral salt reacts with the polysilicates of the soil with the base becoming fixed or insoluble and an equivalent amount of another base being replaced thus: $Alx\ Fex\ Mgx\ Nax\ Ca(SiO_3)x\ (H_2O) + 2KCl = Alx\ Fex\ Mgx\ Nax\ K_2(SiO_3)x\ (H_2O) + CaCl_2$. This equation typifies the metathetical reaction that may take place between a neutral salt and the zeolitic compound of the soil. The $CaCl_2$ is supposed to be in solution.

The fixation of the soluble phosphates is supposed to be accomplished by the bases present in the soil, such as iron, aluminum, tetanium, lime, and magnesium. The reaction which is different from the above is typified by the following equation:

$CaH_4(PO_4)_2 + CaCO_3 = Ca_2H_2(PO_4)_2 + CO_2 + H_2O$.

$Ca_2H_2(PO_4)_2 + CaCO_3 = Ca_3(PO_4)_2 + CO_2 + H_2O$. The soluble phosphate, therefore, reacting with calcium forms insoluble $Ca_3(PO_4)_2$.

According to the physical selective adsorption theory it is suggested that when a soil is in contact with a solution such as KCl it adsorbs the potassium ions at a much greater rate or greater proportion then the chlorine ions thereby, (since an equivalent number of hydroxyl ions are also removed with the potassium ions), causing a partial hydrolysis of the solution, ($KCl + HOH = KOH$ (adsorbed) $+ HCl$), and leaving free acid in the solution which goes to dissolve the soil bases.

Although the last theory might be correct, yet it has not been absolutely proven and does not account for all the facts. The first or chemical theory, however, which seems more rational, explains practically all the facts quite satisfactorily and is probably more widely accepted. In the light of this theory the foregoing question: How is the increase in concentration of the soil solution by the soluble salts brought about? and, What might be the composition of the resulting soil solution?, are explainable, at least partially. For instance, the increase in concentration of the soil solution may not be due to the direct addition of the concentration of the salt solution but that a new compound or compounds might be formed which are in solution and have smaller than or as great lowering of the freezing point as the salt solution added, and that not any of the salt solution added may exist in the original form in the resulting soil solution.

It would be a remarkable coincidence, however, if a new compound was formed in the various mineral soils to which $Ca(NO_3)_2$ was added, which had a lowering of the freezing point as great as this salt solution itself. In a case of this character one is almost led to believe that the entire concentration of this salt solution was simply added to the soil solution without undergoing any change, just as in the case of quartz sand, where the increase in concentration of its solution is due to the direct addition of the concentration of the salt solution.

The almost complete disappearance of the original concentration of $CaH_4(PO_4)_2$, Na_2HPO_4, and K_2HPO_4 solutions in some of the soils tends to confirm the equation already given that these compounds react with the bases of the soils and form insoluble substances and thus the concentration of the soil solution is not at all increased either directly by these compounds or by the formation of new compounds as in the case of neutral salts.

As far as the results of the phosphates are concerned in most of the agricultural soils, they agree with the theory of Whitney and Cameron that the concentration of the soil solution may not be increased by the addition of these compounds, but the explanation, does not appear to be the same.

But as far as the results of the neutral salts are concerned they agree neither with the theory of these investigations nor with the absorption-adsorption theory which postulates that the properties of absorption-adsorption of the soil tend to maintain a constant concentration of solution.

SUMMARY.

The study of the concentration of the natural soil solution is of the greatest importance as well as of the highest interest from all standpoints—the chemical, physical, physiological, and biological. Our knowledge concerning the concentration of the natural soil solution has heretofore been obtained through indirect means, as there has been no method capable of measuring it directly as it exists in the soil and consequently its exact magnitude has not been known, especially under different conditions, including variation in moisture content, fertilizer treatment, tillage, season, etc.

In the present paper the freezing point method has been suggested as a new means of measuring the actual concentration of the soil solution in the soil at different moisture contents and under different treatments. The method is based upon the general principle that the freezing point of water is lowered by the presence of soluble material and that the degree of lowering is proportional to the amount of the soluble material present, (non-electrolytes). The procedure consists of placing a short column of soil in a glass tube 1 inch in diameter and 9 inches long, inserting the bulb of a Beckmann thermometer into this column of soil, then putting this soil tube into another larger glass tube and allowing the soil mass to cool in a cooling bath at a temperature of —4.5°C. After the soil mass has supercooled to about 1°C, the thermometer is jarred or moved in the soil whereupon solidification commences and the mercury thread begins to rise and continues to do so until the proper freezing point is reached where it remains for some time and then begins to fall again. The highest temperature reached on the thermometer is taken as the proper freezing point of the soil.

It has been found that it is extremely easy to determine the lowering of the freezing point of soils. The solidification can be started when the soil mass is supercooled to only about 0.3°C and it is far easier to induce solidification in soils than in solutions. The depression of the freezing point of soils can be measured from any maximum water content down to a very low water content. The minimum water content probably lies slightly below the wilting coefficient of plants. In the case of quartz sand, for instance, the lowering of the freezing point can be measured when the moisture content is only about 0.7%.

The lowering of the freezing point has been determined in a large number of soils at two different moisture contents, low and high. The results of this study show that at the high moisture content the freezing point lowering of all the different types of soil examined is very low and varies only slightly in the different soils. At the low moisture content, however, the lowering of the freezing point is very high and varies tremendously with the extreme types of soil, being highest in clay type and lowest in sand. The amount of concentration and osmotic pressure that are represented by the great depressions in the complex types of soil, are indeed very great. The depression of .955°C of clay, for instance, which was obtained at 18.80% moisture content, represents a concentration of 28,941 p. p. m., and an osmotic pressure of 12.04 atmospheres.

In all the soils, with the exception of quartz sand and some extreme types of sandy soil, the ratio of the lowering of the freezing point is not directly inversely proportional to the ratio of the water content, as might be expected, (approximately), but the former is many times greater than the latter. Thus, in the case of clay the inverse ratio between the lowering of the freezing point and the water content is 27 to 1.85, respectively. Upon investigating this relation more thoroughly by determining the lowering of the freezing point of various soils at a large number of moisture contents it was found that this relation follows a mathematical law and indeed the geometric law, i. e., the lowering of the freezing point increases in a geometric progression while the water content decreases in an arithmetic progression. In the case of quartz sand and some extreme types of sandy soil, however, the depression of the freezing point increases inversely proportional with the water content.

The enormous concentration which the lowering of the freezing point of some soils represents at the low moisture content created at first some doubt as to whether this lowering of the freezing really represents concentration or is caused by some physical factor such as the supposed pressure with which the water films are held by the soil particles, etc. All possible physical factors that might enter into the freezing point have been thoroughly considered but it has not become apparent that the great depressions have been caused by any physical agent. On the contrary all evidences, both direct and indirect, point overwhelmingly to the fact that these high depressions of the freezing point are produced by and represent actual concentration. Thus, washed quartz sand which would not be expected to possess a solution of high concentration causes a lowering of the freezing of only .070°C at 1.5% moisture content, while clay, which would *a priori* be considered as containing a solution of high concentration produces a depression of the freezing point of .955°C at 18.80% moisture content. The rate of increase in the lowering of the freezing point with the decrease in moisture content is uniform throughout, from the maximum to the minimum moisture content, etc.

In explaining that the high depression of the freezing point at the low moisture content, or the increase of the depression of the freezing point with the decrease in moisture content, might represent concentration of solution, the following suggestion is tentatively offered: It is assumed that the soil solution contains salts or their ions, produced by the reaction of the dissolved components of the soil minerals, hydrolysis of the minerals, application of fertilizers, decomposition of organic matter, etc. These salts have, as a rule, a high solubility and would require a large amount of them to form a saturated solution. They are formed relatively slowly and since the frequent and excessive rains, especially in the humid regions, tend to leach them away, only a relatively small amount of them is present at a time. At a high moisture content these salts are diluted and the lowering of the freezing point is small. As the moisture content, however, is reduced, they are concentrated and the lowering of the freezing point becomes greater.

A critical consideration of the character of the soil system and a thorough examination of the available data of the soil solution as obtained through soil water extracts, drainage water, etc., lend considerable support to this hypothesis.

The foregoing hypothesis, however, does not explain why the lowering of the freezing point increases in a geometric progression while the water content decreases in an arithmetic progression and not follow an inverse proportionality law (approximately) as might be expected.

In explanation of this fact the hypothesis is also offered that some of the water contained by the soil might be either loosely chemically combined or physically adsorbed, or both, in which event that portion of the water is not free or available to dissolve the salts in the soil, but is entirely removed from the liquid phase. If it is physically adsorbed it is conceived that it is almost solid like water of crystallization. The hypothesis would seem to explain the results. Thus, for example, if a soil like clay causes 15% of water to become unavailable, or be removed from the liquid phase, and at 36% moisture this soil gives a depression of the freezing point of .034°C and at 18.8% moisture, .955°C, then at the first case there is 20% moisture to dissolve the salts while in the second case there is only 3% of moisture for the same purpose. The depression of the freezing point at the low moisture content, therefore, would be many times greater than that at the high moisture content, than should be expected from the total percentages of moisture content.

While no experimental proof is offered for the above hypothesis there are data which seem to point towards its validity. Thus, it has been observed that at a low moisture content the lowering of the freezing point of all colloidal soils employed, becomes less or smaller with successive freezings. This phenomenon might be explained under the supposition that at least part of the unavailable water is adsorbed by the colloids of the soil. Through the process of freezing this colloidal material is coagulated and thereby releases the adsorbed water which becomes free or available and goes to dilute the original solution.

In the event, therefore, that the lowering of the freezing point at the different moisture contents represents actual concentration of solution, then many extremely important and far-reaching consequences follow: (1). The soil solution is not under all conditions dilute as is generally believed. It is dilute only at the high moisture content, but at a low moisture content and in some soils, it is tremendously concentrated, and this concentration can be increased with the application of soluble salts. (2). The concentration of the soil solution does not remain constant but varies greatly with the moisture content, and the amount and kind of soluble salts added. (3). The soil solution of normal soils in humid regions may never reach a saturation point, in all the salts at least. (4). The magnitude of the concentration of the soil solution is not the same for all soils but varies greatly with the different soils. (5). The absorbtive power of the soils does not seem to influence at all the concentration of the soil solution. Those soils known to possess the highest absorbtive power generally contain a solution of very high concentration, while those that have a low absorbtive power contain a low cencentration of solution. (6). The wilting of plants at a low moisture content may not be entirely due to their inability to obtain the remaining moisture in the soil, but also to the plasmolytic effects of the high concentration of the soil solution.

By means of the freezing point method the effect of application of soluble salts upon the concentration of the soil solution in the soil, was also studied. The compounds were added to the soil in solution in n/100 strength and consisted of KCl, K_2SO_4, $MgSO_4$, $(NH_4)_2SO_4$ $Ca(NO_3)_2$, $NaNO_3$, K_2HPO_4, $CaH_4(PO_4)_2$, and Na_2HPO_4. The soils consisted of washed quarts sand, two different kinds of silt loam, and clay, and one kind of sandy loam, humus loam, peat, and kaolin. The results obtained in this study show that all these compounds have an entirely different effect upon the concentration of the soil solution of the different soils. In the case of the neutral salts the concentration of the soil solution was increased from 20 to 100% of their strength employed, while in the case of the soluble phosphates the concentration of the soil solution of all the soils except peat, quartz sand, and kaolin, was extremely little, if any, increased. These results on the whole do not confirm entirely the theories that the application of soluble salts, even in small amounts, may not increase the total concentration of the soil solution.

THE LEAF-SPOT DISEASE OF TOMATO.

Technical Bulletin No. 25.

FOREWORD.

The importance of the tomato crop in the state of Michigan and the seriousness of some of the losses occasioned by diseases led the Department of Botany to begin investigations on the subject several years ago. The investigation of one of these diseases, the leaf-spot, the subject of this bulletin, was turned over to one of the advanced students, Mr. Ezra Levin, who began work in the fall of 1913 and devoted a very large part of the following school year and summer to the problem. The work was carried out along lines laid down by Dr. G. H. Coons, Research Assistant in Plant Pathology, who kept very close supervision of Mr. Levin's work. The revision of the manuscript and the larger part of the preparation of the Bibliography were also carried out by Dr. Coons. The result of the investigations throw great light upon the structure and life history of the fungus (*Septoria lycopersici*) causing the disease and explain many of the apparently contradictory observations and conclusions of previous investigators. They are of especial value as they show where lie the vulnerable points in the life history of the fungus, an item of the utmost importance in the combating of a disease. Furthermore, the facts learned have been found to shed light upon other diseases caused by other species of Septoria, such as the late blight of celery, etc.

In view of the foregoing it is believed that it is highly desirable to publish the details of the investigations as a Technical Bulletin, for the benefit of investigators wherever the diseases of this type are being studied, and to present the main facts, together with directions for control, in a popular form in another publication.

ERNST A. BESSEY,
Botanist.

THE HOST.

The common commercial type of tomato is *Lycopersicon lycopersicon* (L.) Karst., and is to be distinguished from the currant tomato, *Lycopersicon pimpinellifolium* Dunal, and the cherry tomato, *Lycopersicon cerasiforme* Dunal.

The importance of the tomato crop in the United States is indicated by the following statement from the Thirteenth Census Report: "Judged by value, tomatoes were the most important vegetable, the value exceeding $13,700,000 in 1909." The Michigan tomato crop is extremely valuable. The report credits the state with $217,256, tomato production, and this has since increased to at least five times this amount.

The methods used in growing this crop influence the prevalence of this disease to a great extent.

Seed is sown in hot beds or greenhouses several weeks before setting out; (in Michigan from March to May). In the open, two types of culture are employed: (1) training of plants to two or three stems tied to a stake, (2) allowing plants to grow over the ground at will. In forcing tomatoes, the plants are usually trained to a single stem and staked.

In recent years more and more complaints, indicating the prevalence of serious tomato diseases, have come from the tomato growers of Michigan. The plant disease survey of the state indicated that Septoria leaf-spot was especially serious. Investigation was begun by the writer in September, 1913, and practically completed August, 1914.

THE DISEASE.

The common names by which this serious disease is known are: "late blight," "blight," and "leaf-spot." It is, however, a well known fact that in some sections of the country, tomatoes are attacked by *Phytophthora infestans* (Mont.) de By., the cause of late blight of potato. This precludes the use of "late blight" as a name for this disease. "Blight" and "leaf-spot" are also more or less preempted. The former of these terms or preferably "early blight" may best be associated with *Alternaria solani* (E. and M.) J. and G. which also attacks tomatoes. A common usage among pathologists seems to warrant the name of "leaf-spot" in referring to the diseases of this type.

PREVIOUS INVESTIGATION OF THE DISEASE AND ITS CAUSAL ORGANISM.

It is generally conceded that the fungus, *Septoria lycopersici* Speg. causes the disease commonly known as "leaf-spot" of tomato. As will be seen this has been more of an inference based upon the constant association of the organism with the disease than a conclusion resulting from experimentation.

The organism was discovered in Argentina by Spegazzini in 1882. The fungus and its characteristic lesions were tersely described by him in a publication containing descriptions of several other organisms. The name given by Spegazzini has been in common use for this disease-producing organism although the fungus was subsequently found upon the host in countries far from the source of the type material.

The early accounts of this disease consisted of a few scattered notes recording the finding of the fungus in various localities. For example, as recorded in Briosi and Cavara (1889): Cuboni (1888) and Passerini (1889) found the fungus in Italy. Passerini's contribution is noteworthy in that this author recognized the pathogenic character of the organism and outlined rather fully the symptoms of the disease.

B. D. Halsted (1896; 1897) was the first to report the disease for the United States and in one of his annual reports he listed *Septoria lycopersici* for New Jersey and mentioned it as causing one of the leading fungous diseases of tomato. A. D. Selby (1897a) discussed a "new arrival" in Ohio, apparently *Septoria lycopersici*, and in a later article, its distribution in Ohio was particularly noted (1897b). The same author in 1899 stated—"During the season 1898 conditions of warmth and moisture seemed to favor the development of the Septoria fungus." In 1899, Dr. E. A. Bessey observed extensive damage in Maryland near Annapolis Junction (verbal communication). F. S. Earle (1900) noted a serious epidemic of this disease in the cold frames at Auburn, Ala. N. A. Cobb (1902), discussing tomato diseases of Australia, stated that this disease, "has never been mentioned in this journal (Agr. Gaz. N. S. Wales) hitherto." "The leaves are attacked more particularly although there is hardly any part of the plant entirely free from attack." Again recording the fungus for Australia, D. McAlpine (1903) gave a description of the fungus and the effect produced upon the host. W. A. Kellerman (1903) wrote a brief note on *Septoria lycopersici*. In 1904, W. A. Orton mentioned the disease as serious in the previous year. G. Delacroix (1905) in recording the history of this fungus in France, wrote a description of the causal organism on the host and in pure culture and noted successful infection experiments. (See page 12). L. Reh (1905) described the disease in Germany. G. Köck (1905) noted the disease in Austria. Later he described *Septoria lycopersici*, and made a series of observations on its effects on the host, and resistance of varieties. K. Kornauth (1905) gave a further account of the disease in Austria. J. Burtt-Davy (1905) records the disease from Transvaal. J. L. Sheldon, in West Virginia (1905), noted "Leaf-Spot." B. F. Floyd (1905), in Missouri, described the disease as attacking "leaves, stems, and sometimes green fruit." L. Hollos (1907) described the disease in Hungary. F. D. Kern noted *Septoria lycopersici* in 1906 in Indiana. H. T. Güssow (1908) gave a full description of the disease. This article, dealing chiefly with greenhouse conditions, is an extensive discussion of the fungus and the disease which it produces. The symptoms of the disease are discussed in detail, inconclusive inoculation experiments are reported, and various inferences as to the dissemination of the organism are drawn. F. L. Stevens and J. G. Hall (1909) used *Septoria lycopersici* for experiments reported in a paper entitled "Variation of Fungi due to Environment." This article is chiefly devoted to a biometric study of Septoria fruiting bodies but from it more or less of a description of the organism in pure culture can be gleaned. The Great Britain Agriculture and Fisheries Board (1909) again drew attention to the disease in a popular article taken largely from Güssow's. H. W. Barre (1910) noted the disease and its importance in South Carolina. J. W. Lloyd and I. S. Brooks (1910), Illinois, gave a brief description of "Leaf-Spot." H. S. Reed (1911) reported damage done by the organism in Virginia and gave the most complete description of field conditions of the disease up to that time. Long (1913) gave a popular account of the disease under English conditions. J. B. S. Norton (1914), discussing the disease in Maryland, gave the results of spraying experiments, as well as a summary of the previous spraying tests of other stations.

ECONOMIC IMPORTANCE.

That this disease has long been of importance in different parts of the world is apparent from the reports of N. A. Cobb (1902), D. McAlpine (1903), G. Köck (1905), and H. T. Güssow (1908), to which reference has already been made.

In the United States the disease has spread more or less rapidly, particularly within the last few years. The damage resulting from it ranges from three percent to a total loss of the crop. Practically all the states that raise tomatoes to any degree commercially are more or less troubled with leaf-spot, as is shown by the accompanying map (Figure 1) which summarizes data obtained by a questionnaire, addressed to American pathologists.

The following comments taken from the replies are interesting:

J. B. S. Norton, of Maryland, in answer to the questionnaire states: "The disease causes a loss of 10-25 per cent of our tomato crop. The loss will run into hundreds of thousands of dollars, if not a million." For Missouri, Geo. M. Reed writes: "In some fields perhaps 50% of the early tomato crop is damaged by this disease." N. J. Giddings, of West Virginia: "It is the worst disease which we have on tomatoes in West Virginia." C. E. Durst, of Illinois, states: "This disease coupled with Fusarium Wilt is almost driving the growers out of the business of tomato growing in that section (southern Illinois)." C. W. Edgerton, Louisiana, writes: "Not as yet common but seems to be spreading rapidly. I look for this disease to become serious in this state." It is noteworthy that Septoria leaf-spot has evidently appeared in Louisiana but recently. H. S. Reed (1905): "The culture of tomatoes in southwestern Virginia is becoming increasingly difficult, due to the serious blight and point rot diseases, which have attacked this crop annually for the past five years." On the contrary, H. W. Anderson, Wabash College, Indiana, writes: "In this region we consider it a benefit, since it kills off the leaves near the base of the plant and allows the sun to ripen the tomatoes."

DISTRIBUTION.

In answer to a questionnaire as to prevalence, the pathologists of thirty-four states reported the disease as *common* from the following: Alabama, California, Connecticut, Delaware, Illinois, Louisiana (becoming common), Maryland, Michigan, Missouri, New Jersey, New York, North Carolina, Pennsylvania, and Wisconsin. (Figure 1).

A reply to a similar request to the Bureau of Plant Industry, Plant Disease Survey (Cotton and Truck Disease and Sugar Plant Investigations) for information as to the distribution of the disease brought the following: "Reported in 1903 from Alabama, Connecticut, Missouri, New Jersey, New York, and Ohio; 1904 from North Carolina and Ohio; 1905 from Delaware, Maryland, North Carolina, Ohio, and West Virginia; 1906 from Delaware, Nebraska, New Jersey, Ohio, and West Virginia; 1907 from Delaware, Illinois (mentioned that it has been present in this state for three or four years), Maryland, Nebraska, New Jersey, North Carolina, Ohio, and West Virginia; 1908 from Delaware, Maryland, New Jersey, Ohio, Pennsylvania, and South Carolina; 1909, Delaware, Indiana, Iowa, Maryland, Nebraska, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, and West Virginia; 1910 from Delaware, Indiana, Kansas, Kentucky, (exceptionally prevalent), Maryland, Mississippi, Nebraska, New York, Ohio, South Carolina, Texas, Virginia, and West Virginia; 1911 from Delaware, District of Columbia, Florida, Illinois, Iowa, Maryland, Massachusetts, Missouri, Ohio, Pennsylvania, Virginia, West Virginia and Wisconsin; 1912 from Alabama, Delaware, District of Columbia, Illinois, Indiana, Iowa, Maryland, Michigan, Minnesota, Missouri, New Jersey, North Carolina, Ohio, Rhode Island, South Carolina, Tennessee, Texas, Virginia, and West Virginia." The reply also notes that "The disease may not necessarily have progressed as rapidly as this would indicate but may have been present in all the states earlier."

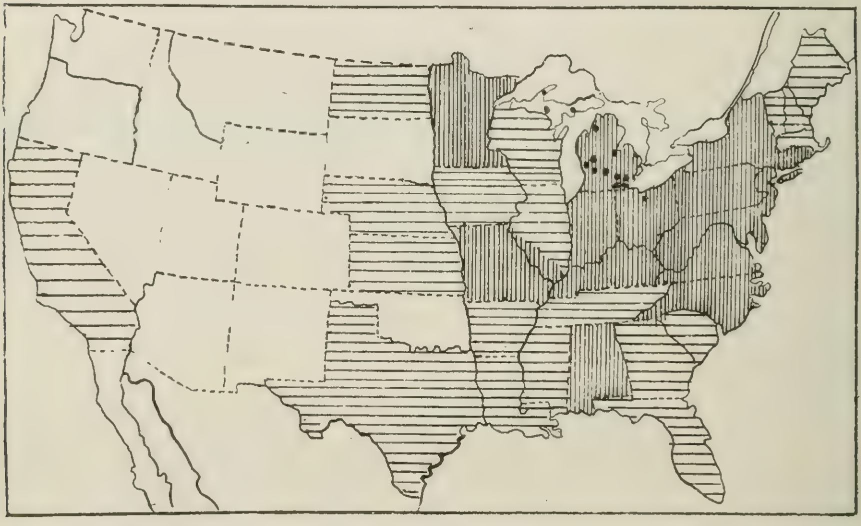

Figure 1. Distribution and relative importance of the Septoria leaf-spot of Tomato, as determined from a questionnaire to American phytopathologists. Collection records from Michigan are shown by dots.

SIGNS.

The general signs of this tomato disease are conveyed by the popular term, "blight." The growers notice a general unthriftiness in their plants, along with a dying of the leaves beginning first with the lower ones and gradually advancing upward on the plant. (Plate 1). The fruit fails to ripen evenly or rapidly, and with severe attack, the entire crop may fail. Such fruit as is produced from diseased plants, lacks sweetness and solid matter. This last condition is often complained of by canners, although they ascribe "watery" tomatoes to wet season, rather than to a fungous disease made severe by the season. In short, all the general signs which accompany interference with the photosynthetic function are to be expected with this disease. The great reduction in leaf surface is accompanied by a reduction of carbohydrate formation.

Along with these general signs of the disease there are distinct lesions on various parts of the plant which allow sure diagnosis.

The fungus causes lesions upon the leaf, the stem, the fruit and the calyx.

On the Leaves:

The earliest indication of the disease is a water-soaked spot which can be distinguished with a hand lens on the underside of the leaf. There is no noticeable discoloration of the tissue at the outset. As the spot grows larger it becomes more or less circular in outline and shows a definite margin. The affected tisssue darkens, becomes shrunken and later appears hard and dry. The color of this spot may vary from black to grayish-white. The spots may vary in shape and size from a small circular spot of pin-head size to a large irregular spot of about 2 cm. in diameter. Not infrequently the spots coalesce. While the tissue is shrinking 3-10 small, black, glistening pycnidia appear in the spot. Finally, yellowish, mucilaginous masses can be seen exuding from the pycnidia. Upon microscopic examination these are found to be masses of long filiform spores. The number of pycnidia in the larger spots may be as high as 30. The pycnidia are well defined, visible with the naked eye and separate (Plate 2.). Pycnidia may occur on the under side of the leaf; usually, however, they occur on the upper side. At this point it must be noted that not all spots contain pycnidia when the leaf dies. This point will be taken up in detail later. (Page 24).

About the time of spore exudation, the green tissue of the leaflet contiguous to the fungous spot begins to turn yellow. This yellowing increases, eventually involving the entire leaflet. Then the fungous spots which have so far been pliable become dry and brittle. The leaflets gradually droop and dry on the stalk which later also shrivels up but remains attached to the stem until broken off by a slight jar. On tomatoes which are staked the disease is sometimes confined to the lower leaves (Plate 1). Where the plants are allowed to trail at will, the disease may cause almost complete defoliation of the plant, the small tufts of young, terminal leaves alone escaping.

On the Stems:

The disease is commonly found on the stems. It is manifested by small, slightly elongated, dark spots containing pycnidia. These spots are not so clearly defined as those on the leaf. The damage to the stem is slight; these spots do not enlarge to form cankers and are not serious except insofar as they produce spores for further infection.

On the Calyx:

Small spots, more or less elongated, occur on the calyx and take a form intermediate between those on the leaves and stems. It may be remarked that the differences in form of the spot are doubtless due to the texture of the host.

On the Fruit:

The disease has never been seen in Michigan as affecting the fruit in the field, however, J. B. S. Norton, (1914) states, "The disease may also attack the fruit, causing dark spots." It will be seen later that artificial inoculation with spores does not lead to infection of fruit, unless the epidermis is ruptured. In general it may be noted that the damage to the fruit by leaf-spot is negligible.

ETIOLOGY OF THE DISEASE.

Previous Work:

H. C. Delacroix (1905) states, "In September, 1904, several attempts at infection were made. The inoculation made on the leaves without wound, simply by placing the spores on them, did not succeed except when the surrounding air was thoroughly saturated, and under these circumstances, I was successful with but one infection. The eight which I tried to inoculate by a very slight scratch on the leaf gave better luck, the infection resulting under these conditions were five out of eight attempts." The only other recorded attempt to determine the pathogenicity of this fungus was performed by H. T. Güssow (1908). "A water infusion of diseased leaf tissue sprayed on a healthy plant." "The whole foliage, stem and young fruits were covered with spots." From the meager experiments of Delacroix the impression that the organism is merely a wound parasite would be justified while the experiment of Güssow is inconclusive.

Formal Proof of Causation:

(a) Constant association of organism with the disease:

Suspected "leaf-spot" material was collected from Earliana tomatoes in the Botanical greenhouse. The typical spots were examined. Pycnidia were found containing long, filiform, septate spores. Comparing this material with descriptions of the fungus from various sources, the fungus was diagnosed as *Septoria lycopersici* Speg.

(b) Pure culture:

A pure culture was obtained by the ordinary dilution methods. The material was carefully washed under a steady, fine stream of sterile distilled water. Pycnidia were crushed on a slide and plates were poured. These were incubated; later single colonies were transferred to nutrient agar. Several days later, these were examined; pycnidia were found in abundance, but no spores were present. Portions of mycelium were transferred to nutrient glucose agar, potato agar, and tomato agar. In eight days pycnidia were found containing typical, long, filiform spores. Subcultures on the same media were made and spores produced in such quantities that the white, glistening mass exuding from the pycnidia was easily perceptible to the unaided eye. This was very fortunate as spores could be obtained free from the mycelium and the other substratum. (See Plate 4).

(c) Production of the disease on healthy plants by inoculation from culture.

A mass of exuding spores from pure culture was shaken up in sterile, distilled water. In the first attempt to produce the disease, thirty-two plants were used.[1] Sixteen plants selected as checks, were sprayed with sterile, distilled water from a DeVilbiss atomizer No. 2. The spore suspension was sprayed upon the other sixteen plants in the same manner, using a similar atomizer. These were all kept under bell jars.

The result was positive but spots on the inoculated plants were very few per leaflet and small. One check plant also showed infection. Many leaflets showed no spots at all, and others showed no more than two. Considering the number of spores applied, and comparing the results with the Van Tieghem cell in which 30% of the spores had germinated, the results were not highly satisfactory.

The following experiment was performed. By means of a platinum loop a drop of spore suspension was placed upon a single leaflet; a very small piece of "White Rose" cotton was quickly spread over it. Twenty-five such inoculations were made. The plants were placed in a moist chamber, in which there was an arrangement to produce a fine mist when desired.[2] In five days every leaflet inoculated showed typical, water-soaked, diseased areas. The uninoculated leaflets were free from disease. Pycnidia were evident after ten days and exudation of white spore masses thirteen days after inoculation. The advantages of this method of inoculation were: the spores were protected by the cotton since the moisture collecting on the leaves did not remove them; the cotton indicated exactly where the inoculation was made; every uninoculated leaflet was a check on the inoculated leaflet.

(d) Reisolation and (e) Reinoculation:

Plates were poured from the exuding spore masses from the pycnidia and reisolations were made to tomato agar, nutrient agar, and potato agar. The identity of the recovered organism was determined beyond question. The cultures so obtained were used successfully in subsequent inoculation experiments.

Infection Phenomena:

The Period of Incubation:

Numerous experiments gave entirely concordant results as to the time necessary after inoculation for noticeable lesions to appear. In the extensive experiment reported on page 33 the daily observation required in this experiment gave abundant opportunity for exact record. The first signs of the spots appeared five days after inoculation. In experiments where inoculations were made on media of various kinds and these media incubated among the inoculated plants to insure more or less similarity of conditions, it is noteworthy to observe that the colony on tomato agar was approximately the same size as the spot on the leaf.

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[1] This work was done in a greenhouse where the temperature varied from 18° C. to 25° C, and the ordinary moist greenhouse conditions prevailed.

[2] A fine jet of water from the tap was allowed to strike the top of a large galvanized iron

This set of phenomena indicated that the initial attack of the fungus produces little effect on the host, and it is only after several days that the fungus, probably by its by-products kills the tissues. While no work has been done with the by-products of this fungus, it may be mentioned that coincident with the killing of the host tissue occurs the darkening of the tomato agar. Experimentation with such products would undoubtedly yield results, opening up a practically untouched field of Plant Pathology.

The Subsequent Development:

On the sixth day submerged pycnidia could be seen in the inoculated leaf. The record with media was similar. On the eighth day the pycnidia were erumpent. Sections at this time showed that spore formation was beginning. On the thirteenth day exudation of spores occurred and this was taken as an indication of maturity of the spores. The record with media paralleled this with the exception that the spore exudations were more extensive in the moist test tube.

Infection and Moisture:

In the experiments so far reported in testing the pathogenicity of the fungus the inoculated plants were left in the moist chamber—sometimes in a chamber filled with a fine spray—for a comparatively long period. Experiments were later inaugurated to find the approximate number of hours requisite in the moist chamber to insure infection.

Previous experiments had shown that 100% infection followed the placing of viable spores on the under side of leaves. The flecks of cotton were found valuable as a marker and as a device for preventing the washing of the spores from leaf to leaf. Five leaflets each of ten strong vigorous plants about 7-14 inches tall were inoculated with spores from the stock pure culture. Nine[3] of these plants were put in the Wardian case which was provided with a jet of water which struck the top and broke into a fine spray. A plant was taken out at intervals of 6, 12, 24, 36, 48, 54, 60, and 72 hours after inoculation. Each plant was immediately dried by the breeze from an electric fan. After an interval of 15 minutes these plants were placed on a shelf in the window of the laboratory. After five days all plants showed typical spots on the inoculated leaves. The other leaves were healthy. That plant which had not been put into the moist chamber showed as typical a case of infection as the others. This experiment is in striking variance to the usual experience with plant pathogenes, since it is commonly stated that the host must be wet for a number of hours at least in order for infection to occur.

On account of this contradiction the experiment was immediately repeated with exactly similar results. The technique of the two experiments was alike with the exception that in the second experiment the plants were kept in the blast of the fan, following removal from the moist chamber, until infection was evident. No variation from the normal time was observed.

An experiment was then performed in which six small plants fresh from the greenhouse were inoculated respectively on the upper and lower leaf surfaces with a loop of spore suspension. The atmosphere in the greenhouse was such that the plants were in a condition of incipient wilting and the water drop disappeared at once. (August, 1914). These plants were then set in the direct sunlight on a shelf in the window. Five of these plants showed typical infection.

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[3] One plant was not put into the moist chamber.

This experiment was repeated using for inoculation the spore mass without making a suspension in water. With a platinum needle a minute portion of this spore mass exuding from a pycnidium was transferred to the leaflets of five plants. The results were similar. All plants were infected after five days. This experiment was performed because it was thought that the drop of spore suspension evaporating, drew the spores into the substomatal chamber. The results indicate that this hypothesis is untenable.

The interpretation of this experiment is rather difficult. There can be no doubt that an extremely small amount of water is necessary to enable the spores to germinate and enter the tissues. This water may be the small amount held upon the leaves, but this is difficult to credit in view of the experiment just reported. The moist air of the substomatal chamber may be concerned. The mucilaginous spore wall undoubtedly clings tenaciously to a small amount of imbibed water. A fact to be taken into consideration in the interpretation of these results is that the spores do not germinate in less than 24 hours in a Van Tieghem cell or on a moist slide. Combining this with these experiments, the results appear most striking. It is possible that the temperature factor is important in this phenomenon.[4] It is evident that if the spore reaches the leaf, regardless of the agent involved, the spore will cause infection, providing the temperature is favorable for the development of the mycelium. It may be that in the case of other fungi as well, current ideas on the necessity of water films and dew for long periods in order to produce infection may be based wholly upon inference.

PHYSIOLOGICAL AND ECOLOGICAL RELATIONS OF THE CAUSAL ORGANISM.

Germination:

To observe the spore germination and subsequent colony formation in various media, the following method was employed: Petri dishes containing Van Tieghem cells were arranged according to Duggar's (1910, p. 59) method. Blotting paper was perforated so that small glass rings would be held in place while being sterilized. (Plate 3, Fig. 1). The media used were cornmeal agar (see appendix), potato glucose agar, nutrient broth, nutrient glucose agar, tomato leaf agar, and distilled water. Solid media, from which hanging drops were made, was melted and cooled to approximately 42° C. An exuding mass of spores was shaken up in each tube. Each Petri dish as described above contained seven Van Tieghem cells. A different medium was used in each Petri dish. Each hanging drop of the medium contained 4-6 spores.

Thus it was possible to make germination studies and observe development (under the microscope) until the organism had attained macroscopic size. The exact time elapsing before germination was difficult to determine, due to the manner of development of the spores. The first signs are manifested in a pronounced swelling of the spore to almost twice the original diameter. Regular, well-defined vacuoles appeared surrounded by dense protoplasm, which made the spore look like a chain. This condition appeared in all the media at the end of twenty-four hours. At the end of 36 hours the end cells of the spores had grown somewhat irregular, slightly tapering, and somewhat narrower than the middle cells. The elongation of both ends of the spore preceding the formation of definite germ tubes was of general occurrence (Plate 9, Fig. 3). Exceptions to this were seen when the number of spores in the hanging drops was increased so that the spores touched.

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[4] These experiments were performed from August 15 to 31.

After 48 hours, germ tubes were formed varying from 1 to 4 for each spore. The germ tube may grow from any cell. (Plate 9, Figs. 1 and 2).

One may consider the germination of the spores as beginning either with the formation of the definite germ tube or with the growth from the terminal cells. In many spores instead of developing germ tubes immediately, the terminal cells elongate and then branch. The other cells in the spore may or may not send out germ tubes. For the first four days, the germination phenomena and initial colony formation are much alike in various media (Plate 9, Figs. 4 and 5). With the subsequent growth, differentiation takes place.

In the Van Tieghem rings with nutrient glucose agar and potato glucose agar a very luxuriant growth took place. The four-day-old colonies were readily visible to the unaided eye. The hyphae were richly branched, with prominent oil drops, and were very striking because of their irregular contour. (Plate 9, Fig. 7, Plate 8, Fig. 5). After six days, the medium became brown, and after eleven days, the mat-like stroma was so thick that observation with a microscope was impossible.

In distilled water the ring cultures made but slight growth other than germination and no sporulation was seen.

Cornmeal agar and tomato-leaf agar gave a moderate growth in marked contrast to the media rich in sugars. After four days, secondary spores—long filiform structures arising from small papillae on the mycelium—were found in tomato-leaf agar and two days later in the cornmeal agar. After eleven days, some of the threads of mycelium became dense brown. (Plate 9, Fig. 6). This condition was found in both cornmeal and tomato-leaf agar. (Plate 8, Fig. 4). Pycnidium formation was noticeable after the eleventh day. (Plate 9, Fig. 8).

In nutrient broth cultures, a diffuse rapid growth took place. The hyphae were narrow and regular, and were not profusely branched. On the sixth day, secondary spores were found. Five days after formation it was found that these secondary spores had germinated forming new colonies. (Plate 8, Fig. 3). Others produced secondary spores immediately after elongation (Plate 8, Fig. 2). After eleven days pycnidium formation was evident throughout the culture.

The observations may be summarized as follows:

1. Spore structures, evidently secondary spores, are formed abundantly in various media. These may germinate and form new colonies. This contradicts Delacroix (1900) who states, "The stylospores germinate easily in water and nutritive liquids by the production of a septate, branching filament *without* the formation of secondary spores."[5]

2. The presence of a distinct type of mycelium; whether this mycelium is a special stroma or pycnidial mycelium has not been definitely de-

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[5] As the nutritive liquids used were not mentioned, repetition of Delacroix's experiment was not possible.

termined. It is believed that these hyphae (as a base) become associated with the hyaline hyphae to form the pycnidial wall. It might be mentioned that all media become strongly browned immediately after the pycnidia begin to form. The source and nature of this browning must remain for future investigation.

Growth on Media:

Macroscopic Cultural Observation:

The following media were used: Cornmeal agar, nutrient glucose agar, prune juice agar, tomato agar, nutrient saccharose agar, nutrient broth, bean pods, potato plugs, tomato leaves, tomato stems, cornmeal and rice.

Spores from pure culture were inoculated into three tubes of double distilled water so that a microscopic examination gave about 36 spores in a loop. One loop of spore suspension was introduced in each tube of media. This experiment was carried on in triplicate, one tube being sealed with sealing wax,[6] three tubes of each medium making up one series. Five of these series were arranged. These were allowed to grow at room temperature for 48 hours; Series 1 was placed in the greenhouse under the plants that were severely affected with the disease (Approximately room temperature); Series 2 in the ice box, (Approximately 12°); Series 3 in 37½°; Series 4 (room temperature, about 21° C.) on shelf in the window of the laboratory; Series 5 (room temperature) diffused light.

In the accompanying table the growth on different media for 3, 6, 8, 10, 12 and 18 days respectively is described for Series 1. Series 3 made no growth whatever at 37 ½° and after ten days was placed at room temperature but did not revive. All the other series were so nearly identical that it is needless to differentiate between them. The organism made no growth on bean pods. Tomato agar and cornmeal agar were found to be the best media. In the former the growth simulated more closely than in any other medium, the growth on the leaf. The excessive stroma production found in other media was absent. The pycnidia were separate and distinct, the development almost identical as to the time necessary for pycnidia production after inoculation. The tomato agar seemed to inhibit the growth of molds and bacteria when plates were poured from field material. The use of the autoclaved tomato leaf was also very satisfactory, although here no definite spots or colonies were formed, the growth being diffuse.

The following table gives the result of this experiment:

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[6] Reported on page 23.

TABLE 1. GROWTH OF *SEPTORIA LYCOPERSICI* ON VARIOUS MEDIA:

Media.	3 Days.	6 Days.	8 Days.	10 Days.	12 Days.	18 Days.
Tomato agar..........	Colonies slightly larger than after 48 hrs.; mycelium scanty, medium beginning to darken; indefinite brownish spots in colonies.	Increased growth; colony 3 mm. diam. distinct black pycnidia submerged 4-7 per colony, separate.	Pycnidia larger; mycelium slightly increased; more pycnidia forming. Darkening of medium mycelium submerged.	No stroma, pycnidia glistening, erumpent, mycelium no increase.	White spore masses exuding from pycnidia perceptible to naked eye. Spore masses as large as pycnidium.	Spore masses increase in size. Growth stopped.
Corn-meal agar........	Colonies no larger, but turning brown, medium beginning to darken. Mycelium both submerged and aerial.	Mycelium slightly increased, brownish green, slight evidence of pycnidial formation.	Pycnidia distinct, submerged; separate, mycelium slightly increased.	Pycnidia larger, still submerged. Mycelium scanty and very dark.	Pycnidia slightly erumpent, glistening black, all mycelium darkened, colonies distinct.	Spores exuding. Grayish white masses with pycnidia separating from the colony sitting on the surface.
Nutrient Glucose agar...	Darkening of medium. Abundant mycelium, spreading, dark except on edge of colony.	Growth raised, spreading; mycelium below surface scanty. Pycnidia formation very abundant, contiguous; colonies coalescing.	Pycnidia erumpent, black mycelium only seen on edge of colony. Entire growth made up of pycnidia.	Pycnidia erumpent, grayish black, surrounded by aerial mycelium. No increase in colony growth.	Several exuding spore masses. Mycelium grayish dirty white.	Spores exuding, grayish white masses abundant. Colonies erumpent, separate. Pycnidia contiguous.
Prune Juice agar.......	Abundant mycelium, slightly spreading, aerial, white.	Medium darkening, mycelial stroma becoming erumpent, mycelium slightly spreading in definite dark spots.	Pycnidia formation submerged in stroma, contiguous, stroma very erumpent, not spreading.	Mycelium darkened, stroma formation. Evidence of pycnidial formation.	Black erumpent pycnidia. No mycelium in evidence.	Spores exuding, white masses from a few pycnidia.
Tomato Stem..........	No signs of growth.	Colonies with white mycelium in evidence at different points on stem.	2 colonies on one of 3 tubes, other 2 contaminated. Slight darkening. No evidence of pycnidia.	Pycnidia forming, mycelium spreading, aerial and submerged.	Pycnidia increased in number. Erumpent, glistening black.	Exuding spores from some pycnidia, white spore masses of pycnidia.
Tomato Leaf...........	No signs of growth.	Slight aerial mycelium, white.	No darkening of tissue. Small black specks at point of inoculation.	Increased growth; mycelium, aerial, pinkish.	Evidence of pycnidia on edge of colonies. Medium black on which colonies are growing.	Pycnidia erumpent, sparse, mycelium scanty. No signs of exudation.
Rice..................	No signs of growth.	Slight darkening of medium with evidence of mycelium on edge.	Medium black, colonies slightly increased. No signs of pycnidial formation.	Pycnidial formation contiguous. Mycelium in slight evidence, pycnidia covering entire colony.	Pycnidia erumpent, greenish yellow, spreading mycelium.	Stroma with embedded mycelium, white aerial mycelium. Exuding spores pinkish masses, long and slimy exudation.

Corn-meal	No signs of growth.	Slight darkening of medium. Mycelium spreading, flat submerged and aerial.	Increased darkening, spreading. Signs of pycnidial formation, mycelium yellowish.	Slight evidence of pycnidia formation in black stroma.	Pycnidia formation submerged, black, dull, covered with a black mycelium.	Pycnidia clearly distinguished spore formation. No exudation.
Nut. Sacc. agar	Darkening of medium, abundant mycelium, not spreading, black grayish white mycelium on edge of colony.	Growth raised, mycelium superficial. Pycnidial formation becoming erumpent. Colonies coalescing.	Pycnidia erumpent, colonies erumpent, pycnidia covering entire colony growth except the edge which is dirty gray mycelium.	Increased growth spore formation. Very erumpent colonies. Medium darkened.	Spore exudation. No spore masses, but exudation spreading.	Grayish mycelium growing above colonies.
Nut. Broth	White mycelial colonies 6 mm. diameter.	Increased size.	No evidence of pycnidial formation.	Those colonies that were attached to side of test tube darkening, evidences of pycnidia formation.	Erumpent pycnidia, 3-7 on colony.	Exuding spores, white spore masses.

Relation to Various Factors:

Desiccation:

Exuding spore masses from a pure culture, in which spore masses had just appeared were transferred to 15 sterile cover slips in a Petri dish. A spore suspension was made from spores from the same culture and a drop of it was placed on each of 15 other sterile cover glasses. These were kept in a sterile Petri dish when dry. After varying lengths of time (see table) these slips were lifted with a sterile forceps and planted in tubes to tomato agar. The results were as follows: (+) indicating growth; (—) no growth.

TABLE 2.—EFFECT OF DESICCATION: TEST WITH SPORE MASSES AND SPORE SUSPENSION.

Started 9-11-14. Spore Masses.	Started 9-14-14. Spore Suspension.
9-11-14 9 P. M. +	9-14-14 10 A. M. +
9-12-14 9 P. M. +	9-15-14 10 A. M. +
9-14-14 10 A. M. +	9-16-14 10 A. M. + (?)
9-15-14 10 A. M. +	9-17-14 10 A. M. +
9-16-14 10 A. M. –	9-18-14 10 A. M. –
9-17-14 10 A. M. –	9-19-14 10 A. M. –
9-18-14 10 A. M. –	
9-19-14 10 A. M. –	

This experiment determined the resistance to drying as well as the lack of influence of the matrix upon this resistance. This experiment shows that the spore, whether in mass in the mucilaginous matrix or isolated will not resist drying more than four days. The practical application of this experiment is obvious.

Heat:

As was indicated (Page 17) an entire set of cultures on various media were incubated at 37½° forty-eight hours after inoculation at room temperature (23°). These failed to develop. Furthermore, after taking these out, fifteen days later, and allowing them to remain at room temperature for four weeks, no sign of growth was evident.

This was verified by inoculating 10 tubes of tomato agar; five were placed in 37½° C. incubator, five were retained at room temperature (about 23° C.). The tubes which were incubated at 37½° C. failed to develop, while the check tubes developed normally. The tubes were removed after 5 days and kept at room temperature but did not revive after being kept one month at 23°.

Observations in the field and of material sent in from various sources, indicated a peculiar range in the size of spots. Pycnidia were present but the actual spot formed varied greatly. Some leaves would show numerous small spots separate and distinct from one another, covering the entire leaf. On some leaflets the disease was manifested as one large spot. These variations might be dismissed as due to weather conditions. But, if it is possible under ordinary weather conditions to find spots of pin-head size, may it not be that there are some weather conditions which entirely inhibit the development of the organism? That this hypothesis is tenable has been demonstrated by experimental evidence. Inoculated tubes of cornmeal agar were allowed to develop for 48 hours and were them placed in an incubator at 29°. These did not grow further in the incubator. However, when taken out to room temperature these revived and grew normally. In this experiment two tubes were taken out each consecutive day after being placed in the incubator. When comparing all the tubes after ten days, the checks which were not put into the incubator at all, showed the greatest development, while the other tubes indicated a gradual lesser development respectively until finally the tubes taken out on the day of observation showed no development. All the tubes grew normally at room temperature maintaining a difference in growth as indicated by inhibition for 24 hours. That this is important practically, is obvious. It opens up a line of investigation which might make it possible to know what kind of weather is favorable to the fungus not from observation and hearsay but from actual laboratory tests. The lack of apparatus made it impossible to make these investigations more extensive.

However, to determine whether this would be verified on the living plant, the following experiment was performed. Two tomato plants of the same age and size were inoculated in the following manner. A spore suspension was made from a pure culture and one loop of this suspension was used for each inoculation. Twenty inoculations were made on each plant, ten on the lower surface of the leaf and ten on the upper surface. One plant was placed in the cool part of the greenhouse and the other was placed in the warmest part of the greenhouse. The first plant was placed at an average temperature of 23° C., and an average humidity of 63%. (These averages obtained from Lambrecht polymeter readings made several times a day). The second plant was placed so that the average temperature was 28° C. while the average humidity was 55%. All inoculations were successful. The plant under the cooler conditions showed difference in the lesions produced depending on whether upper or lower surfaces were inoculated. The inoculation on the upper surface gave spots 2-3 mm. in diameter, while those on the lower surfaces gave larger dead areas, 4-6 mm. With the plant at the high temperature, the spots produced by inoculations on the lower surface closely resembled those of the upper surface of plant 1, while the spots resulting from inoculations on the upper surfaces of the leaves were mere points. Eight infections of the ten were less than 1 mm. in diameter and the other two were but slightly larger.

This experiment indicates the difference in results obtained with upper and lower surface inoculations. There is also shown the effect of high temperature in inhibiting this organism while in the plant. Incidentally, this experiment indicates that a saturated atmosphere is not essential for infection to take place. The small loop of spore suspension with which the inoculation was made, disappeared almost at once when placed upon the plant. (See page 14).

Thermal Death Point of Spores:

This was determined by the method advocated by Novy (1899, p. 515) for use with bacteria. A spore suspension in 100 cc. of sterile distilled water was made using spores from a pure culture containing exuding masses 2 or 3 days old. These spores were placed in a shallow dish and then allowed to rise 5 or 8 cm. in a thin-walled capillary tube made by drawing out a sterile glass tube of about 4 mm. diameter. After the suspension had been drawn to the requisite height in the tube, the height can be determined by the slant at which the capillary tube is held, the end which dipped in the suspension was sealed in the flame of a microburner. Then the capillary tube was scratched with a file about half an inch beyond the liquid, broken and sealed. At one time about two dozen such spindles were prepared, and were ready for use in the experiment. The use of such small quantities of spore suspension in thin-walled tubes enables the entire mass to reach the desired temperature quickly after submersion in the water bath.

A series of water baths made of heavy cast iron were filled with water at the desired temperature. Each bath was equipped with a Bunsen burner. By varying the height of the flame and frequent observations, it was possible to maintain the temperature within the range of ½ degree. Temperatures ranging from 40° to 60° C. by gradations of 2½ degrees were used. After an exposure of ten minutes the spindles were removed and dropped into cold water. A nick was filed near one end, then the tubes were rinsed in $HgCl_2$, followed by two changes of sterile water. One tip was broken off with flamed forceps. By gently heating the unbroken tip the contents of the tube were quickly forced out into the test tubes of media. The results were as follows:

TABLE 3.—THERMAL DEATH POINT OF SPORES: TEST WITH CAPILLARY TUBES

40°	+	52½	−
42½	+	55	−
45	+	57½	−
47½	+	60	−
50	+ (?)		

It may be concluded that the spores will not grow after being subjected to 52½ degrees for ten minutes. However, it is worthy of note that the number of spores which germinated and grew in tubes 40°—42½—45, were much more than that of 47½° and 50. At 50 only 6 colonies grew; at 47½, 15 colonies, while at 40—42½—45, the growth covered the entire surface of the medium and appeared exactly similar to check tubes. This resistance of certain spores raises the question whether these spores are especially heat resistant due to protoplasmic properties and whether the growing of these would give a heat resistant strain. This unfortunately could not be followed to a conclusion.

Relation to Light:

The Influence of Sunlight:

Three plates of cornmeal agar were poured using exuding spores from a pure culture. Two plates were exposed to the sun for three hours. After three days colonies were in evidence, with no perceptible difference in growth of exposed plates and check. Five inoculations were made on young tomato plants and exposed to the sun from 11:00 A. M. to 2:00 P. M. Five inoculations were made as checks. The inoculated plants developed typical infection, showing that for a period of at least three hours the sun had no effect upon the development of the organism. This verified the results obtained by exposing the spores in poured plates of cornmeal agar for the same length of time.

Comparison of Growth in Light and Dark:

Fourteen tubes of nutrient glucose agar were inoculated with exuding spores from a culture upon tomato agar. Seven tubes were wrapped in black paper (such as is used to cover photographic films). These were placed in a closed tin vessel and with the checks were placed in a dark corner of the room. After seven days, examination showed no difference excepting those in the light developed aerial mycelium. This was absent in the tubes which were covered.

It has been mentioned above (page 17) that in the experiment dealing with the growth of the organism on various media, Series 1, was placed in the greenhouse under the plants which were severally attacked by the disease. Series 2 was in the ice box. Series 4 on shelf in the laboratory window and Series 5 in laboratory but in diffused light. The results indicated that these series were indistinguishable in their development.

Relation to Oxygen:

It was mentioned also (page 17) that the experiment was carried on in triplicate, one of which was sealed. When these were examined it seemed that some tubes showed exactly similar development to the unsealed while others of the sealed tubes indicated a very scanty growth. This incongruity was explained when it was found that every "sealed" tube which appeared similar to the unsealed tubes had developed small pin holes in the sealing wax. While conclusions can hardly be drawn from such an accident it may be well to note that there was no gradation from the sealed to the unsealed; the pin holes evidently serving as efficiently for the air supply or circulation as the larger and loose cotton plugs. In the tubes which were competely sealed, slight development was evident, but no pycnidia were observed.

Dissemination:

The connection of the organism to some ascomycete is commonly postulated. This postulate receives support from analogy with other Septorias (Klebahn, 1908). Potebnia (1910, p. 167) has expressed the opinion that the viability of conidia of a Septoria after wintering indicates loss of the ascomycetous stage. This certainly finds no substantiation in other ascomycetous life cycles, and is not sufficient ground for elimination of the possibility of the possession of an ascus stage. Attempts were made to find this hypothetical ascomycetous form, but were unsuccessful. Affected leaves were buried at various depths in the ground, November, 1913.[7] A careful examination of this material in March, April, and May, 1914, failed to reveal an ascus form. Old, diseased stems from the previous year's crop were examined with negative results. Dried pure cultures on cornmeal were examined, revealing no perfect stage.

It is noteworthy that on the wintered stems and leaves a remarkable increase in the fungus thallus had occurred, forming a conspicuous stroma, in which the pycnidia were immersed, without however, the loss of identity of the pycnidial walls. Statements, without citation of experimental work, have been made that the fungus lives over on the trash, (Cook, 1913, Stuckey, 1915), and on greenhouse frames and sashes (Güssow, 1908). Spores from pycnidia found upon wintered over vines were put in Van Tieghem cells. Ten per cent of the spores showed active germination. It cannot be definitely affirmed that this is the only source of infection in the field. The possibility that *Septoria lycopersici* may have some ascomycetous stage must necessarily hold in abeyance the problem of primary infection. It is very probable that part of the infection, at least, is produced by pycnidia in the old trash. The greenhouse or hot bed in which young plants are grown is an important source of infection. Seeds are planted under glass three or four weeks before they are set out in the field. Allowing five days for germination and appearance of the cotyledon there is a period of nearly three weeks in which the fungus may spread. As has been shown the period from the time of inoculation until the time of spore formation, is on the average 13 days under favorable conditions. Thus at least one secondary infection is possible after the primary infection. This infection usually shows as a series of spots about the older spot and is doubtless due to the floating out of spores from the exudations of the first formed pycnidia. Because of the comparatively long period between inoculation and spore formation, leaves are frequently found with large blotches and comparatively few pycnidia. These blotches with only a few pycnidia might be mistaken for the lesions of *Alternaria solani*.

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[7] Two pieces of wire mesh (4 mm.) 12 inches square were used for this purpose. These were lined with a thin layer of cotton which was thinly covered with fine sand. Infected leaves and stems showing abundant pycnidia were placed between these wires. This was submerged in a sandy loam soil near the greenhouse at an angle of 30° with the surface of the soil, the top slightly projecting, exposing about 3 inches of the wires.

The diseased cotyledons soon fall off and the plants are seemingly clean but a latent colony may be present on the leaves.

Numerous instances have been reported of the appearance of the disease in greenhouses in which tomatoes have never grown before. This indicates the possibility of transferrence of the fungus on the seed. Washings from tomato seeds have been centrifuged and examined repeatedly without successful results although the spore is characteristic enough to enable recognition.

It is believed, however, that the main source of infection is the trash from a previous tomato crop. It has been repeatedly demonstrated that rotation of crops diminishes the severity of Leaf-spot. If the infection came principally from the greenhouse, this rotation could hardly be so effective.

The agencies, aside from man, by which transferrence takes place are mainly water, and wind. The matrix in which the exuding spores are embedded holds the spores upon drying. These spores can be released only when soaked and in this condition they may be washed down by dew or rain. In culture pycnidia with exuding spores have retained those masses for a period of 3 months without dislodgment or germination. After this time tomato plants were inoculated with a suspension of spores and typical infection resulted. The matrix may have more or less of an inhibitory effect on the spores. A mass of spores from a newly formed exudate was placed in hanging drops but no germination resulted. Yet this retardation of germination may be due to the effects of the spores on each other, a condition strikingly illustrated in heavily seeded plates. (Stevens and Hall, 1909).

The dew washes or floats the spores about on the leaf. This causes the secondary infection which has been described. A large number of spots on the leaf usually do not develop pycnidia before the leaf dies and shrivels up. However, this dead, dried leaf which falls to the ground, if kept at all moist, has been found to develop mature pycnidia and exude spores more profusely than upon the living plant.

The important agency in dissemination is the splashing of the rain.

The rain may carry the spores from the old, diseased leaves on the ground to the healthy leaves above, or from the diseased leaf to the leaves surrounding it. It will be recalled that in staked tomatoes the disease progresses upward beginning at the lower leaves. It is a significant fact that the spots on the lower leaves are large, indicating infection from the lower surface, while the top leaves show the characteristics of upper leaf surface inoculations.

The relation to water was demonstrated in the greenhouse. Twelve plants were grown and staked. The cotyledons of these plants were diseased. These were not removed and were allowed to fall off. The plants were watered from above twice every twenty-four hours. After two weeks all the lower leaves developed typical leaf-spot. Two weeks following, these lower leaves developed a number of secondary spots and were beginning to shrivel and dry up. The leaves above these were in about the same stage as the first leaves two weeks before. The disease spread rapidly progressing upward on the vines. When the disease had advanced about 3 feet above the soil level, 10 healthy tomato plants were transplanted between these diseased plants. Watering from above was discontinued, being replaced by careful irrigation. The plants set between the diseased plants did not develop the disease even after twenty-five days. Watering from above was now resumed and in six days the leaves of all the young plants were covered with spots.

This experiment determines the fact that the spores do not fall or float from the pycnidium as soon as produced but adhere in a mass until liberated by water. In answer to the criticism that infection did not take place because of the dryness of the leaves, it may be said that the greenhouse was always humid and furnished ideal conditions for spore germination. The experiments already reported demonstrating the independence of infection and humidity also remove any objection to this interpretation of the foregoing experiment.

The wind, as an agency in the spreading of spores, may be considered as carrying the dust which contains the spores, thus inoculating other plants. The spores germinate in a filtered soil infusion, secondary spores being produced. Viable spores have also been found in the soil about diseased plants. However, experiments performed to determine the development of the organism in the soil yielded negative results; considering that exuding spores are washed down on the soil from the diseased leaves, it is very probable that the dust must be considered as an agency for dissemination of the fungus, limited however, by the length of time the spores can stand drying and the disintegrating action of the soil.

In this connection the difference in type of infection on upper and lower leaves may be significant. The lesions on the lower leaves are of the type to indicate infection from the lower leaf surface. It is easy to conceive that the top leaves—especially when the plants are staked—are out of the zone reached by splashings of rain, but especially open to infection brought by falling dust particles.

That man is an agent in spreading disease is very evident. In cultivating the plants when they are wet, the spores are transferred to all parts of the field by the machinery coming in contact with the sticky spore masses or upon the clothing. Instances of dissemination in this manner have been observed.

MORPHOLOGY OF CAUSAL ORGANISM.

The Spore:

The spores of the Septoria stage are filiform and hyaline varying from 60-120 microns in length to 2-4 microns in thickness, divided into from 3 to 9 cells. The thickness of a spore is not uniform throughout. The shape of the ends varies from pointed to globose. (Plate 8 Figure 1).

The Mycelium:

The mycelium of this fungus is composed of frequently septate, vacuolate threads. These threads have a diameter of from 2 microns to 3 microns. The mycelium may be said to show two types—the hyaline thin-walled type, and the dark, closely-septate, heavy-walled type. The former predominates during the vegetative stages of the growth while the latter precedes the stroma and pycnidium production. The character of these types of mycelium is brought out by figures. (Pls. 7 and 8).

The Pycnidium:

A number of tubes of tomato agar, cornmeal agar, and nutrient glucose agar were inoculated with a pure culture. At the end of every 24 hours after the colony was visible to the naked eye, material from these tubes was killed in Flemming's medium fixing fluid. Material was killed on successive days until exuding spore masses were in evidence.

The following schedule was followed:

Flemming's medium	24 hours
Washed in running tap water	6 hours
15% Alcohol	15 minutes
39% Alcohol	30 minutes
50% Alcohol	1 hour
70% Alcohol	Over night
80% Alcohol	2 hours
95% Alcohol	2 hours
Absolute Alcohol	2 hours
⅓ Cedar Oil — ⅔ Absolute	1 hour
⅔ Cedar Oil — ⅓ Absolute	1 hour
Cedar Oil	1 hour
Cedar Oil ÷ paraffin	6 hours
Paraffin	2 hours

Transferred to new paraffin (52°) and embedded after 2 hours. Some sections 5 mm. thick were made. Stains used; Flemming's Triple, Delafield's haematoxylon, Haidenhain's haematoxylon.

Continuous efforts were made to obtain results with Delafield's haematoxylon and eosin as described by Durand (1911), but with no success. Although the time which the slide was immersed in eosin was varied from 2 seconds to 5 minutes, the carbol turpentine was inadequate to remove the excess stain. Durand's method was then changed in a single particular and excellent differentiation resulted; after immersing the slide in eosin, the excess stain was washed off with absolute alcohol for a second, then was immersed in carbol turpentine and was mounted in balsam. The result was that the mycelium became a deep red and was very easily distinguished from the surrounding tissue.

As a result of a study of a culture on tomato agar after 62 to 96 hours, the following steps in pycnidium formation were observed:

The mycelium begins to anastomose and interweave, becoming browned, resembling a closely woven net, so that the fungous tissue seems to be made up of individual cells more or less rounded in shape. This small oval body increases in size while the surrounding mycelium sends out branches which augment this globose body. This enlarging continues 24-92 hours. At the end of this time, the pycnidium consists of a hollow, globose body, without an ostiole, and is 100-375 microns in diameter, with a few strands of mycelium crossing the cavity within. (Plate 5, Fig. 1).

Spore formation takes place in the same manner as described in the formation of the secondary spores, except that no definite elongated projection that might be considered as a well differentiated conidiophore is formed. The cells that give rise to the conidia are hyaline, resembling the peridial cells and can be traced to the brown thread from which they have arisen. Spores are produced to such an extent as to burst open the peridium at its weakest point and form an exuding spore mass sometimes twice as large as the pycnidium from which it arose. Usually that part of the peridium that is exposed is entirely broken up by the mass of spores. Plate 4, Fig. 1 illustrates this observation. In the pycnidium shown, (Plate 7, Fig. 2), the weakest point of the wall must have been submerged in the agar so that the thick part of the wall exposed to the air remained intact, while the exuding mass forced itself into the agar.

However, for complete elucidation of the method of pycnidial formation of this fungus, the development and formation of the fruiting body, must necessarily be studied in the host. Eight plants were inoculated. After three days, just as soon as the infection was visible as a small water-soaked spot, material was killed in Flemming's strong medium. Material was killed every day until the exudation of the spore masses began. The formation of pycnidia and spores was found to be identical in every particular to that described for agar cultures. The development of the pycnidial wall takes place in an exactly similar manner as in artificial media. After the "balling" up of the mycelium, the hollow case grows larger and larger, after which the spores are formed. These same sections also allowed the nature of the forces acting on the pycnidium to form the ostiole to be definitely determined. Due to the relation of the pycnidium to the surrounding tissue, the mature pycnidium finally comes to possess a more or less broad ostiole as has been pointed out by previous investigations. The steps in its origin seem to be as follows:

Soon after the pycnidium begins to form, two forces are in evidence:

1. That brought about by the enlargement of the pycnidium.
2. That brought about by the shrinking of the adjoining tissues of the leaf (a condition which can be readily seen with the unaided eye). The enlargement of the pycnidium may cause a rupture of the epidermis of the host by an upward pressure or if the fruiting body be completely embedded within the leaf tissue, there is no rupture of the epidermis.

While this fungous wall (only 3-5 cells) is pushing itself outward, the surrounding tissue is beginning to shrink due to the activity of abundant mycelium in the surrounding tissue of the latter, while the epidermis which had previously remained attached to the top of the pycnidium, begins to exert a dismembering force on all sides of the pycnidium. The great excess of this tension over the strength of the wall results in the pulling apart of the pycnidium and the formation of the so-called "ostiole." (Plate 7 shows this very clearly.) Along with this, the pressure of the spore mass no doubt, contributes to the rupture by its action at the point of greatest tension. In event, however, the pycnidium is formed within the tissue so that it does not protude above the surface of the leaf, or as in many cases only slightly, with the peridium remaining intact, the only factor entering into the forming a "broad ostiole" is this pressure of spores. Spores begin to form *after the peridium has developed* exactly as they are produced in culture (see above). As soon as one spore is formed another arises from the undifferentiated hymenial layer. In such a manner, spores are produced in great abundance until they completely fill this pycnidium. This mass of spores becoming larger and exerting a gradually increasing force upon the thin 3-5 celled wall, suddenly *breaks* through this pycnidial wall at the point of least resistance. This point of course is usually the part of the pycnidium nearest the upper or lower epidermis of the leaf. At no time has a definite pre-formed ostiole been observed in culture or in the leaf. In culture, the mass of spores finding the weak point in the pycnidium in the submerged part of the fruiting body, forces itself into the agar (Plate 7, Fig. 2) breaking off the lower half of the wall, the remains of which were easily determined. It will be recalled by those who have seen various Sphaeropsidales in culture that the presence of an ostiole can often be clearly distinguished before spore exudation. The entire pycnidial formation in this fungus is strikingly different from that in the regular ostiole-forming pycnidia. There is no doubt but that in this matter of presence or absence of ostiole we have a phenomenon which could readily be made of taxonomic significance. (Von Höhnell 1911).

The Name of the Causal Organism:

Recently Diedicke (1912) in his critical revision of the Genus *Septoria,* limited this genus to forms whose fruiting layer is enclosed in a pseudopycnidial case, which is equipped with a more or less broad opening. This work was strongly confirmed by the previously published work of Klebahn (1908) and Potebnia (1910). At this point the work of Potebnia may be cited rather fully.

In a chapter on Septoria, Phleospora, and Rhabdospora he writes, "These three genera were in general placed with the Sphaeropsidales, while in Saccardo's Sylloge (III, 577; XI, 398; XXI, 975) the position of the genus Phleospora is not determined and is placed with both the Sphaeropsidales and the Melanconiales. Those species belonging here which were studies by me show that the three genera are closely related and properly do not constitute typical Sphaeropsidales forms, because the fruiting bodies are not built as typical pycnidia. The commonly tender wall of the fruiting body consists of a network of hyphae, which lines the cavity in the leaf tissue made by the destroying activity of the fungus. Such fruiting bodies are named "Pseudopycnidia." The development on artificial substrata in the majority of species of the three genera studied is in agreement. At first the conidia-forming mycelium is produced, then there arise the "Klumpen" or "Ballen," in which Klebahn has shown for Phleospora ulmi, pycnidia (Septoria or Phleospora), and micropycnidia (Phyllosticta) are formed."

So firmly convinced is Diedicke (1912) of the potency of this distinguishing characteristic and of. its taxonomic importance, that he would exclude all forms lacking this pseudopycnidium from what he considers true Septorias. This he has already done with at least two species. Diedicke would put the forms possessing Phoma-like pycnidia into the genus Rhabdospora. Thus in this classification the limits of Rhabdospora are circumscribed, and the old distinction emphasized by Allescher (1901). The occurrence on stems as contrasted with Septorias' occurrence on leaves, is discarded. Recent work on the Sphaeropsidales has proved the highly artificial character of this distinction. (Hedgcock, 1904, Harter, 1914).

The writer is wholly in accord with revisions of old genera when such revisions are based upon comparative morphological work with adequate materials. Adequate materials must be taken to mean fresh material from the host and from cultures rather than the fragmentary, dry material from exsiccati. Hand sections from their very meagerness and uncertainty cannot be relied upon. Without, at present, going into the merits of the case, this paper records the strong difference of morphology in *Septoria lycopersici* from that found in certain other Septorias, (Potebnia, 1910; Diedicke, 1912; and others).

If the name Septoria is to be applied to forms having *pseudopycnidia*, then a new genus must be provided for the tomato organism. At present more than 25 Septorias are being investigated in a similar manner to that described in this organism, and decision is withheld pending these studies. Accordingly the old genus name is retained.

The Species Name:

Spegazzini (1882)[8] first found the fungus in Argentina, South America. The Italian investigators noted a discrepancy in the description as applied to the Italian form, for Briosi and Cavara (1889) in their description of the fungus, state: "The leaves of the tomato attacked by this fungus show very numerous roundish or oblong spots, yellowish or ash colored with a thin darker margin. Perithecia appear on the upper surface. There also are found some on the lower surface of the leaf." "The perithecia are immersed in the tissue of the leaf, and have globose form, sometimes somewhat depressed, and have a parenchymatous wall, thin and olivaceous in color, and possess a broad ostiole. The spores escape in an agglutinated mass, and are of various lengths." (On the accompanying drawing the spore measurements are given as 40-120 x 2-3 microns).

"This parasite causes great injury, and attacks, according to Passerini, not only the leaves but also the stem and fruits. Furthermore, the characters which it showed in our specimens distinguished it somewhat from those indicated by Spegazzini. It does not form, as the author says, great spots which occupy almost the whole blade, nor are the perithecia scattered and mostly hyphophyllous and lenticular or hemispheric. Whence Passerini observed justly in his recent note, 'If it is not a species entirely distinct from *Septoria lycopersici* Speg., our form would at least be a form or local variety, varying from it by external characters.' "

In view of these observations, Briosi and Cavara named the leaf-spot in their locality, *Sept. lycopersici* var. *Europaea.*

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[8] Spegazzini's description as given in Saccardo III, p. 535, is as follows:
Maculis magnis saepe totum folium occupantibus, sordide fuscocinerescentibus, subindeterminatis; peritheciis sparsis saepius hypophyllis, lenticular-hemisphaericis, prominulis, atris, membranaceis, contextu parenchymatico, olivaceo; sporulis bacillari-cylindraceis, bacillari-subclavulatis majusculis, 70-110-3, 3-pluriseptatis, utrinque obtusiuscule attenuato-rotundatis, hyalinis. *Hab.* in foliis languidis *Solani Lycopersici* in hortis, Boca del Riachuelo Argentinae.

Comparing the manifestations of the disease on various specimens from different localities, it was observed that the American specimens agreed closely with the description by Briosi and Cavara. Hence, it would seem that the fungus in this country answers to the description *Sept. lycopersici* var. *Europaea*.

However, observation of the fungus under a variety of conditions shows that there is not enough significance in the minor variations in size of spot, emphasized by Passerini to warrant the establishment of the variety.

As has been shown (p. 15), the size of the spot formed depends upon the number of spores with which the leaf is inoculated as well as upon which surface the leaf is inoculated. With a pure culture[9], in experiments determining the pathogenicity of the organism, a spot involving the entire leaf was frequently found. Spores from the same pure culture produced typical round spots when the spore suspension was further diluted. Spots arising from inoculation on the upper side of the leaf are much smaller and darker than those spots produced by inoculation on the under side of the leaf. In the field, the spots were very variable in size, depending upon the weather conditions. In cooler weather larger spots were produced than in hot weather. It was observed that spots formed in the secondary infection were much larger than in the primary infection. Spots with hypophyllous pycnidia were very common, both epiphyllous and hypophyllous pycnidia being usually found in the same spot. However, as a rule, the pycnidia are on the upper side of the leaf. Microscopical examination of large numbers of prepared slides showed all graduations from lenticular to globose pycnidia.

These observations are merely mentioned at this point to indicate that the activities of the fungus, affected by environmental conditions, cause manifestations sufficiently varied so that peculiarities of the lesion, which may be only functions of the intensity of attack, can hardly be sufficient basis for the formation of a new species or variety. Such a segregation to be valid would need to be based on carefully controlled conditions of the host and fungus.

The *Exsiccati* specimens accompanying the description by Briosi and Cavara were examined and could not be distinguished from specimens from American localities.

The only part of Spegazzini's description, then, which does not coincide with the manifestations as observed in this country is that the pycnidia are "most frequently" hypophyllous. Whether this is evidence that a different species or variety exists here is a question which is yet to be settled. [10]

If there is sufficient evidence that the fungus in Argentina is distinct, then it follows that we must necessarily have a name for the form found here.

The important point that must be noted is that regardless of nomenclature, the form in Europe seems identical morphologically with that found in this country. This must be recognized in all discussions of experiments performed by European investigators with this fungus.

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[9] In this paper all the work was done with the progeny of a single spore isolated as described on page 12.

[10] Material has been sent to Spegazzini for comparison with his type material, and with the organism as now found in Argentina.

Pending a comparison of the Septoria Leaf-spot from Argentina, the specific name *"lycopersici"* is used.

RELATION OF FUNGUS TO HOST.

Morbid Anatomy:

The Spore on the Host:

In order to follow the course of infection, inoculations were made on a number of plants. The epidermis was stripped off from the inoculated leaves at intervals of 6-12-24-36-48 hours. Examination showed germinating spores; at the end of 48 hours these appeared similar to spores in culture. (See p. 15). The great number of spores lengthened and grew from both ends. This was soon followed by germ tubes arising from various points on the spore. The type of infection is stomatal. (See Plate 4, Fig. 2). The mycelium may immediately enter a stoma. The spore in making its primary terminal growth in germination may enter the stoma, or if the mycelium does not come in contact with stoma immediately, the germ tube may branch and grow over the surface until it strikes a stoma. No chemotactic action leading to the finding of the stomata seemed to be manifested.

Mycelium and Tissues:

Infection may occur on both sides of the leaf. Careful study of the two types of infection were made in the various experiments when infection was desired. It was noted that when spores were placed on the upper surface of the leaflet, infection was manifested in small, narrow spots with from one to five pycnidia; the infection being more or less confined to the midrib and veins of the leaflet. Infection produced by placing the spores on the lower side of the leaflet resulted in a broad, spreading spot, and resembled for the greater part, field infection of the lower leaflets, spots forming at all points of the leaflet. This was verified by using one standard loop of spore suspension for inoculation on the upper and lower surface of leaflet, respectively.

Haustoria:

Immediately on entering the stoma, knob-like haustoria developed (See Plate 6, Fig. 2). These may be formed at once upon entering if the mycelium touches the cell wall. By enzymic action, the haustorium merely dissolves the cell wall, but does not penetrate deeply into the cell. A gradual shrinking of the pierced cells results. The mycelium grows luxuriantly through the leaf, making its greatest growth in the spongy tissue. At the end of five days the tissue is partly disintegrated and pycnidia begin to form. The mycelium commences to ball up and enlarge.

The mycelium is not confined to the disintegrating tissue. It is found in abundance through the tissue contiguous to the spot, in most cases terminating at the tracheary cells. In this outside tissue the cell relations are similar to the cells at the point of initial infection after the mycelium had grown for four days.

The period from the fifth to the thirteenth day after inoculation is characterized by the gradual shrinking and blackening of the tissues. From the half-submerged pycnidia the spores ooze out. The white spore masses are similar to those produced in culture. They arise in a spiral form when the opening is small. When the opening is large, they resemble those in culture. The leaves do not suffer severely from the primary infection. When two or three spots are present on a leaflet, it begins to droop and the entire leaflet turns yellow. When the spores from these spots have been washed to all parts of the leaf by the dew or rain, infection may again take place and the spots appear just as the leaf shrivels up and dries. If the spores are present in abundance the leaf will die after the first infection, if a large number of spots are formed.

This condition is usually present when the tomatoes are allowed to run over the ground. The first condition is more typical of staked tomatoes. The reduction of the photosynthetic area of the plant impoverishes it and reduces the quantity of fruit produced. The fungus attacks old and new leaves alike, but due to the incubation period of five days, a vine that was almost completely defoliated will have a small tuft of terminal leaves.

Morbid Physiology:

The causal organism in its attack on the leaves eventually produces defoliation and the effect of this is evident, not only in the size of the crop, but upon the character of the fruit produced. There is, however, a period when the leaves are spotted but not otherwise affected, and then follows a period in which the spots, while not enlarging, evidently influence the plant, causing a yellowing of the adjacent tissue.

Work by Galloway (1896) with a rust of pine seemed to indicate that the cause of the vast disturbance of the pine leaves followed by leaf cast was due to the excessive water loss which took place from the rifted epidermis. This conclusion is warranted from his readings. Moreover, the whole biology of the evergreen needle seems to indicate that it may be especially susceptible to a transpiration shock such as must result from a strongly perforated epidermis; but in the tomato disease the epidermis remains intact and the yellowing proceeds very slowly and the leaves do not manifest the characteristics of transpiration shock. Moreover, the recent work by Reed and his associates, Cooley (1913) and Crabill (1915), on Gymnosporangium raises important questions. These investigators did not find an acceleration of transpiration from diseased tissue.

The conclusions of Reed could not be used directly for the fungus under discussion due to the strikingly different habit on the host. Rusts are known to conserve the tissue of the host, at least until after fruiting, while with this fungus the host cells attacked were killed in a very few days and previous to fruiting body formation.

An experiment was conceived which would aim to determine the influence of the disease upon transpiration. Due to the ease with which the tomato plant is infected by this fungus, and also, because of the general structure of the tomato plant, the experiment was possible on a larger scale than has ever been used in similar investigations. Twenty-two tomato plants were grown under identical conditions in the Botanical greenhouse from seed of Earliana variety. The soil of the pots was sifted twice before being placed in these receptacles and was saturated but not water-logged. The pots were prepared as follows:

A number of stiff one-pound cheese cartons (upper diameter 10 cm., bottom 7 cm.) were arranged to serve the same office as the aluminum shells used in the plant physiological laboratory. The lower third was cut off and the top portion fastened to Petri dishes with paraffin. After the paraffin had hardened, more melted paraffin was poured into the dish and the pot containing the plant was set into this paraffin before it hardened. Holes were made in the covers for the stem and corks. (Plate 3, Fig. 2). The transpiration performance of the plants was observed for a period of five days, May 2nd to 6th, inclusive, loss of weight being made up daily. At the end of this time, the number of leaves ranged from four to seven with leaflets on each leaf varying from three to seven.

Inoculations were made by placing two loopfuls of a pure culture suspension upon the lower surface of each alternate leaflet of eleven plants. The other plants were held as checks. The checks and inoculated plants were kept in a moist chamber for a period of four days to insure strong infection.[11] This was the only interval in which no weighings were taken, otherwise every twenty-four hours from May 2nd to May 20th, weighings were made and water added to bring back the original weight except that on May 12th, ten extra c. c. were added to each plant to allow for the increase in growth.

In order to determine the increase in leaf area from the time of inoculation to the time of cessation of the experiment, the following method was employed. By means of an adjustable glass plate and a tungsten light, prints were made on contrast paper (Cyko) of each leaf on every plant. These were developed and fixed in the usual manner. This was done just before inoculation, and immediately after the last reading on May 20th. By means of a planimeter, the area of the prints at various periods was obtained.

The disease was severe enough to cause the death of approximately two-thirds of the tissue of every leaflet inoculated. The tabulated data indicate the weighings and water added during the performance period when no plants were inoculated, and the last six days when 11 of the plants were infected.[12] This gives the data as to the amount of transpiration from the time that infection was visible to the first signs of general yellowing (break down) of the leaves. It is particularly necessary to bear in mind this point since this experiment was concerned only with the spots formed by the fungus and not with the secondary yellowing of the leaf which follows infection.

TABLE 4.—TRANSPIRATION OF HEALTHY AND DISEASED PLANTS: TEST BY WEIGHING PLANTS AND MEASURING LEAF SURFACE.

Performance record for first 5 days of experiment.				Performance records of checks and diseased for last 6 days.			
Condition of plant.	Av. area (1) in sq. meters.	Av. daily transpiration.	Transpiration per sq. m. per hour.	Av. area (2) in sq. meters.	Av. daily transpiration.	Transpiration per sq. m. per hour.	Area 2 ÷ 1.
Healthy thruout..	.00862	13.	62.8	.02376	32.67	56.93	2.47
Inoculated after first 5 days....	.00904	13.1	60.3	.02214	30.9	58.2	2.88

[11] At that time the independence of moisture and infection was not known.

[12] The detailed tables are given in Appendix, those given in the text being summaries.

The above table emphasizes the similarity of the check and inoculated plants. Starting with the same average leaf surface and same transpiration per unit of area, even after more than ten days invasion by the fungus, we find the average area and average transpiration approximately the same. The difference in growth was not great.

If we examine the individual plants we are struck by the ranges in each of these relations; but careful comparisons will show that no greater variation occurs in the inoculated plants than occurs in the check plants. Moreover, both sets, before the inoculation took place, showed a similar variability. Our experiments cannot hope to avoid errors which come under this head. The number of plants possible for manipulation is so few in comparison to the number needed to eliminate error from this source, that it can hardly be hoped that experiments of this type can ever be entirely free from this factor. The following points may be made:

The method of obtaining the area eliminated a large source of error commonly present in area determination. The method of obtaining the amount transpired per plant was accurate to at least ½ gram, if not 1-10 gram. Moreover, the amount used is an average of several readings. The amount transpired per unit of area in the unit of time is very similar in each average.

Considering that in the inoculated plants, ⅔ of each alternate leaflet was diseased, we have the striking conditions of almost identical performance.

Necessarily the interpretation of this condition affects the whole experiment. We can have the following possibilities:

(1) Healthy and dead areas transpiring alike.
(2) Dead areas allowing more evaporation.
(3) Dead areas hindering water loss.

Were the first case true, the similarity of ratios is very readily accounted for, but then the death of the leaf, and the reduction of vitality must be explained on grounds other than mere water loss.

In event of the second, the yellowing of the leaves, the leaf-cast, etc., could readily be attributed to excessive water loss. Since, however, the ratios of transpiration for the leaves are almost the same, we need to postulate a repression of transpiration from the living areas.

In case the third condition were true, we need to postulate an augmented evaporation from the unaffected portion of the leaves, and attribute this to a chemical stimulation perhaps, from the by-products of the fungus.

To decide which of these conditions really existed, the following experiment was performed, with leaflets in early stages of the disease, and with leaflets which had been diseased for some time. Leaflets showing a few well defined spots were attached by the petiole to small rubber tubes. Other parts of the leaf were cut away and the cut surfaces covered with vaseline. All manipulations of attaching leaf to the rubber tube were carried on under water. The rubber tube was then attached to a potometer set up as shown in diagram. (Figure 2). In order to have conditions of humidity and temperature constant, the work was performed in an enclosed chamber (approximately 2 feet in each dimen-

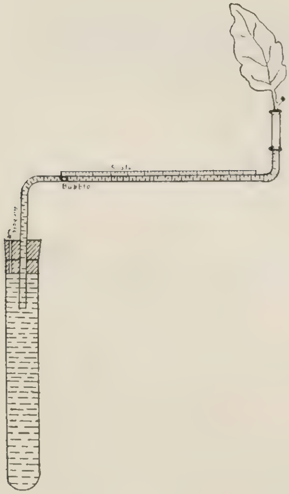

Figure 2. Diagram of potometer used to determine if diseased spots transpire.

sion). Three Lambrecht polymeters were placed in various parts of the chamber and the thermometers and hygrometers were read at each reading of water loss. The day was rather moist, and no variation occurred during the experiment. After noting the transpiration over a definite period, the diseased spots were carefully vaselined on both sides; and transpiration was noted as before. The following results were obtained:

TABLE 5.—TRANSPIRATION OF LEAFLETS IN EARLY STAGES OF DISEASE: MEASUREMENTS OF AREAS AND DISEASED SPOTS.

Condition of leaflet.	Area of 1 surface.	Number of spots on leaflet.	Diseased area 1 surface.	Per cent of leaflet diseased.
1. Leaflets green; spots pliable........	1.6 sq. in. (by planimeter)	9	.054 sq. in.	3.3%
2. Leaflets green; spots pliable........	2.05 sq. in.	5	.03 sq. in.	1.4%
3. Leaflets green; spots pliable........	2.4 sq. in.	32	.192 sq. in.	10. %
4. Leaflets green; spots pliable........	2.3 sq. in.	7	.084 sq. in.	3.6%
Average....................	....	....	....	4.8%

TABLE 6.—TRANSPIRATION OF LEAFLETS IN EARLY STAGES OF DISEASE: PERFORMANCE OF POTOMETERS.

Potometer	Movement of bubble before diseased spots were vaselined.		Movement of bubble after diseased spots were vaselined.		Rate (a).	Rate (b).	Ratio of water of movement b ÷a.
	Time.	Spaces.	Time.	Spaces.	Before (spaces per min.)	After (spaces per min.)	
1..............	33 min.	9	123 min.	27	.27	.22	.81
2..............	83 min.	12	74 min.	41	.749	.51	.70
3..............	40 min.	22	103 min.	29.5	.55	.19	.35
4..............	41 min.	22.5	114 min.	31	.54	.27	.50
Average...	....	....	....	....	....	....	.59

TABLE 7.—TRANSPIRATION OF LEAFLETS IN LATER STAGE OF DISEASE: MEASUREMENT OF AREAS AND DISEASED SPOTS.

Potometer.	Condition of leaflet.	Area of 1 surface.	Number of spots on leaflet.	Diseased area (1 surface).	Per cent of leaflet diseased.
5.........	Leaflet yellowed; spots dry	1.4 sq. in. (by planimeter).	16	.192	13%
6.........	Leaflet yellowed; spots dry	.5 sq. in.	11	.08	16%

TABLE 8.—TRANSPIRATION OF LEAFLETS IN LATER STAGES OF DISEASE: PERFORMANCE OF POTOMETERS.

Potometer.	Movement of bubble before diseased spots were vaselined.		Movement of bubble after diseased spots were vaselined.		Rate before (a) (spaces per min.)	Rate after (b) (spaces per min.)	Ratio of rates of movement (b ÷a).
	Time.	Spaces.	Time.	Spaces.			
5..............	42 min.	2.5	92 min.	5.5	.06	.06	1.
6..............	39 min.	7	88 min.	13.5	.18	.15	.83

In the cases where the leaflets were green and spots pliable, (Tables 5 and 6), the decrease in rate of transpiration after the vaseline was applied is far greater than the mere decrease in transpiring surface would warrant. Although the spots were on an average only 4.8 per cent of the total leaf surface, the transpiration was cut down nearly one-half (.59) by vaselining the spots. This indicates that in early cases of attack, the diseased spots evaporate more than the healthy portions.

In the potometers with the yellowed leaves, (Tables 7 and 8), there was little or no transpiration from the diseased spots, indicating that with complete desiccation and shrinkage, the spots are cut off from the water supply.

Of the three possibilities outlined on page 34, the experiment points to the second case where the diseased areas transpire more and the healthy portions of the leaflets less, but the writer is fully aware of the meagreness of his data.

IMMUNITY PHENOMENA.

Cross Inoculations:

The following plants related to the tomato were inoculated by placing a loopful of spore suspension from a pure culture on various leaflets.[15]

Solanum quinescens
Capsicum frutescens
Nicotiana tabacum (tobacco)
Solanum tuberosum (potato)
Solanum villosum

Within five days the potatoes showed definite small black spots on all the inoculated leaflets, while the check leaflets showed no infection. None of the other plants showed any spots.

The experiment was repeated with the same results. Various attempts to find pycnidia in the infected areas of the inoculated potato leaves have failed in these preliminary experiments. This is a most interesting result inasmuch as no Septoria has been described upon potato (Saccardo). It is also hard to explain the absence of such a record in view of the frequent association of tomatoes and potatoes in the field, unless the failure to produce pycnidia is a uniform condition. More extensive experiments are planned. At present, it is important to note that these spots were obtained by merely applying the spores, not injuring the tissue in any way. The importance of further investigation upon this point is obvious.

Susceptibility of Varieties:

The following varieties were obtained from D. M. Ferry & Co., Detroit, Mich., Vaughan Seed Co., Chicago, Peter Henderson & Co., New York, to whom thanks are due:

D. M. Ferry & Co.

Perfection
Buckeye State
Ponderosa
Peach
Magnus
Beauty
White Apple
Early Detroit
Early Michigan
Stone
Acme
Matchless
June Pink
Golden Queen
Dwarf Champion
Chalk's Early Jewel
Coreless
Earliana

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[13] The leaflets not inoculated acted as checks.

Peter Henderson & Co.

Perfection
Tenderloin
June Pink
Crimson Cushion
Chalk's Early Jewel
Beauty
Early Freedom
Dwarf Champion
Stone
Livingstone's Globe
Ponderosa

Vaughan Seed Co.

Red Plum
Bonny Best
Trophy
Stone
Livingstone's Beauty
Ponderosa
Crimson Cushion
Freedom
Dwarf Stone
Matchless
Magnus
Acme
Earliest of All
Perfection
Livingstone's Favorite
Pear-shaped Red
Sutton's Best of All
Enormous
Lorillard
Yellow Plum
Fall Champion
Sterling Castle
Pear-shaped Yellow
Atlantic Prize
Red Cherry
Frogmore Select
Honor Bright
Comet
Sunrise
Hubert's Marvel
Hummer
Red Currant
Golden Queen
Yellow Peach
Vaughan's Model
Ground Cherry or Husk
Livingstone's Globe
Cream City
Red Peach
Chalk's Jewel
Early Michigan
Imperial
Coreless
Buckeye State
June Pink
Early Detroit
Dwarf Champion
Dwarf Aristocrat

Ten plants of each of the varieties listed were grown. Five were inoculated after the method previously given, five were left as checks. Every inoculated plant developed the disease except the Currant tomato and the Ground Cherry. The Currant tomato, however, is by most systematists classed as a different species, and this relation to a pathogenic fungus is believed by many to be a confirmatory test of a *specific* entity. The Ground Cherry belongs to another genus (Physalis). This experiment was not intended to determine the relative effect of the disease on the plant in the field. There are a number of factors which these results do not recognize; the ability of the plant to form new leaves, the mechanical structure of the leaves, etc. This experiment, however, does point out that in the common varieties of the tomato, with this particular organism, there is no variety strikingly immune or susceptible to this disease.

It is believed in various sections of the country that the Globe is a resistant variety—this statement being often seen in horticultural papers. G. Köck (1907) classes certain varieties as resistant, less resistant, and strongly susceptible, as follows:

Resistant—Wonder of the Market, Up-to-date, Mikado, King Humbert;

Less Resistant—Magnum Bonum, Prelude, Ponderosa, Pres. Garfield and Alice Roosevelt;

Especially Susceptible—Trophy, Ficarazzi.

The varieties tested appeared neither more or less strongly affected than any other. From investigations carried on, it is found that there is no evidence of a distinction, even in the size of the spots formed among these varieties, provided the spore suspension is applied to the lower part of the leaf with relatively the same number of spores in each inoculation. G. Köck does not mention his method in arriving at his conclusions. This, of course, precludes the possibility of comparison of results. Judging from his article he relied merely on field appearances. It is interesting to contrast the following observations by J. B. S. Norton (1914): "Practically all the varieties grown in America and Europe have been tried here the past two years, and all showed about the same amount of Septoria Blight on the foliage. Some varieties are, however, more vigorous growers and continually keep ahead of the blight by the production of new foliage."

Here as in all work on resistance and immunity in reference to plant disease, the whole matter of resistance and susceptibility is obscured by disease *Tolerance and Escape.* (Orton, 1908; Freeman, 1911). We might add to this the ability to repair or replace damaged tissue. In view of the total lack of any superiority of any one variety in the experiments reported, the writer feels that the explanation of Norton is correct and the rapidity of growth of some varieties (as contrasted with the slowness of the dwarfs) is responsible for the apparent cases of resistance to disease of certain varieties of the tomato, *Lycopersicon lycopersicon.*

RECOMMENDATIONS FOR CONTROL MEASURES.

Before control measures can be considered, we must recognize the following observations that have been dealt with above:

1. The sources of infection are at least two: the greenhouse or the hotbed and the old trash in the field.
2. Infection results from inoculation upon the upper and lower surfaces of the leaf.
3. The period from the time of inoculation to spore exudation is about 13 days.
4. Moisture is the primary agent in dissemination of the disease.
5. The exudate of spores is in the form of a mucilaginous *mass*. The spores are always transferred by some external agency.
6. It has been shown that the mycelium will not grow at 37½° F., (98° C.) and will not revive after ten days at this temperature. Since this temperature is frequently reached during the summer months, this must be taken into consideration as a natural means of checking the disease.

The most important control measures for this disease are prophylactic. Clean seedlings in clean soil, if reasonably isolated remain practically free from the disease.

In order to be sure that the seedlings do not become diseased at the start, clean soil should be used in the greenhouses devoted to seedling production. The soil should be fresh or sterilized. The seedlings should be sprayed as soon as their height above ground makes it practicable, and again before being transplanted to the field. For this a weak Bordeaux mixture (2-2-50) is advised.

Since it has been determined that wintered-over, diseased vines possess spores which are viable, the old trash must be destroyed as far as possible. Since, however, this is not practical except in greenhouses and gardens, rotation is strongly urged. While there is no experimental evidence to demonstrate the value of rotation as a means of control, numerous instances have been noted in which rotation has been successful in controlling the disease.

After transplanting to the field, spray with 4-4-50 Bordeaux mixture every 10 days. As has been shown, the period from time of inoculation to spore exudation is at least 13 days. Allowing this leeway for differences in period of infection, it would seem that a spray so applied would give the necessary protection.

The greatest part of and the strongest infection results from inoculation on the lower surface of the leaf. Therefore, all these precautions are less effective if the plants are allowed to run at will over the ground. The spraying of the under side of the leaf is not accomplished unless the application is thorough. Failures to control the disease by spraying are doubtless due to lack of thoroughness and timeliness.

Moisture acts as a mechanical factor in disseminating the disease in two ways. (1). The dew carries the spores from the mucilaginous mass to all parts of the leaflet to form secondary infection. (2). The rain by splashing, carries the spores from the ground below to the leaves above and in a similar manner carries the spores from the diseased leaves on the ground to the healthy leaves above.

The mucilaginous matrix holds the spores until they are released by contact with some object. When the plants are dry, the spores do not float in the air or fall from the leaf but stay embedded in this matrix, which becomes hard and strongly cohesive.

Accordingly the plants should not be "worked" when wet. Growers have reported cases where cultivation began at a small infected patch and the disease was carried over the entire field, and that in less than three weeks the entire field was spotted. This is now readily explained. In greenhouse practice, irrigation should replace the ordinary use of the hose.

Spraying with 4-4-50 Bordeaux mixture in the fields where tomatoes are staked should be extremely successful. In this state spraying will not pay unless the spray reaches the lower surface of the leaves. A sprayer such as is used for potatoes, with two side nozzles set to shoot upward and if practical, with one central nozzle to spray downward for each row will, under high pressure, be most efficient in Michigan fields.

SUMMARY.

This bulletin gives the results of experiments with the Leaf-Spot disease of tomato and recommendations for its control. After a discussion of the previous work on the disease, the disease is discussed under topics:—Name, Economic Importance, and Distribution. The disease manifests itself by forming lesions on leaves, stems, calyx, and fruit.

Since previous work for the most part inferred the connection of the associated fungus and the disease, or at least was not entirely conclusive, formal proof of parasitism was undertaken. This work proved that the organism, *Septoria lycopersici* Speg., causes the disease. Studies of infection phenomena were given under the topics:—Period of Incubation, Subsequent Development, and The Relation of Infection to Moisture.

The physiological and ecological relations of the causal organism were studied under the topics:—Germination, Growth on Media, Relation to Dessication, Heat, Light, Oxygen, and Dissemination.

Morphology of the causal organism indicated that the pycnidium is a closed ball with a wall similar to that in the genus Phoma. The spores are long and needle-shaped bodies with pointed or rounded ends, usually with several septa. The mycelium is of two sorts. The morphology of this organism shows a striking difference from that found in the members of the genus Septoria studied by Potebnia, Diedicke and Klebahn. There is no proof available to show that the organism in the United States is different from that in Argentine, hence the specific name, *lycopersici,* is retained.

In considering the relation of the fungus to the host, it was found that the type of infection is stomatal. The mycelium is intercellular and possesses haustoria.

An experiment to determine the morbid physiology of the plants infected by Septoria indicated that healthy and diseased plants transpired nearly alike per unit of area. There was, however, an indication that the diseased spots transpire more than the healthy portions of the affected leaves, and that the transpiration of these healthy portions is repressed below normal. The fungus was found to infect the potato when the latter is artificially inoculated. No fruiting bodies were produced in the disease spots. No variety of tomato was found especially susceptible or immune although more than fifty were tried. Control measures, chiefly prophylactic, are recommended.

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APPENDIX.

Media Used in Cultural Work with the Fungus.

Cornmeal Agar (Shear):

Four teaspoonfuls of yellow cornmeal were added to a liter of distilled water. Digested in water bath below 60° for one hour, 1.3% agar was added and boiled for 45 minutes; water lost added; albumen of two eggs added for clearing. Filtered through absorbent cotton and tubed. Autoclaved 15 minutes 110°

Prune Juice Agar:

One hundred twenty gms. of dry prune flesh. Boiled in one liter of distilled water in steamer for two hours. Filtered through cheesecloth and 12 gms. of agar added. Boiled two hours in steamer until completely dissolved. Cleared with albumen of two eggs. Filtered through absorbent cotton. Autoclaved 15 minutes 110°.

Tomato Leaf Agar:

Green tomato leaves were pressed and 60 cc. of juice was boiled in 500 cc. of water and then 12 grams agar flour was added to juice, boiled 45 minutes and cleared with albumen of two eggs. Filtered through cotton. Autoclaved 10 min. 110°.

Nutrient Glucose Agar:

Digested 20 gms. of agar in 500 cc. of water. Dissolved in 500 cc. of water 40 gms. of glucose, 3 gms. of beef extract, 3 gms. of salt, 20 gms. of peptone. Poured into agar and steamed for 45 minutes. Cleared with albumen of two eggs. Filtered through absorbent cotton. Autoclaved 10 minutes at 110°.

Nutrient Saccharose Agar:

Digested 30 gms. of agar in 500 cc. of water. Dissolved in 500 cc. of water 40 gms. of saccharose, 3 gms. beef extract, 3 gms, salt, 20 gms. peptone. Poured into agar and steamed for 45 minutes. Cleared with albumen of two eggs. Filtered through absorbent cotton. Autoclaved 10 minutes at 110°.

Nutrient Broth:

Dissolved 3 gms. of Leibig's beef extract in a liter of water to which was added 10 gms. peptone, 5 gms. of common salt; neutralized with normal NaOH to 1° Fuller's Scale. Autoclaved 10 minutes at 110°.

Bean Pods:

Canned bean pods placed with ½ inch distilled water in test tubes. Autoclaved at 110° fifteen minutes.

Potato Plugs:

Potato plugs made with cork borer. Soaked in running water 24 hours. Placed in tubes in bottom of which a small wad of cotton soaked in distilled water was placed. Steamed three consecutive days for 15 minutes.

Tomato Leaves:
Young leaves were cut from growing vines. These were placed in test tubes with 2 cc. distilled water. Autoclaved at 110° for 5 minutes.

Tomato Stems:
Stems were prepared in the same manner as the leaves.

Cornmeal:
A teaspoonful of cornmeal in large test tube to which was added four times volume of distilled water. Steamed 3 consecutive days for 15 minutes.

Rice:
Rice was prepared in the same manner as cornmeal.

TABLE 9.—TRANSPIRATION RECORDS OF HEALTHY PLANTS IN EXPERIMENT REPORTED ON PAGE 33: PLANIMETER READINGS MADE IN SQUARE INCHES.

Healthy throughout.

Plant.	Water loss in grams.					Total loss in 120 hrs.	Average daily transpiration.	Area in sq. in.	Area in sq. m.	Transpiration per sq. m. per hour.
	May.									
	2.	3.	4.	5.	6.					
1	10.	9.	8.3	3.	6.	36.5	7.3	13.95	.005510	55.17
2	26.5	27.5	23.	9.	13.	32.27	19.8	32.27	.01277	64.68
3	16.	19.	17.5	7.5	12.	72.	14.4	21.60	.00858	69.8
4	9.	9.5	10.	4.	6.	38.5	7.7	15.38	.00607	52.82
5	17.	19.	17.	7.5	13.	73.5	14.7	27.98	.01104	55.42
6	14.	16.	13.	4.	7.5	54.5	10.9	14.72	.00582	77.95
7	14.	13.5	11.	4.5	11.	54.	10.8	21.27	.008405	53.5
8	19.	16.5	13.5	2.5	12.5	64.	12.8	21.19	.00837	63.7
13	21.	21.	20.	8.	15.	85.	17.	30.22	.01195	59.25
14	33.5	30.5	24.5	12.	20.5	121.	24.2	37.67	.01490	67.8
16	18.	17.5	14.	7.5	12.5	68.5	13.7	23.67	.008365	68.25
Average							13.	21.81	.00862	62.8

Plant.	Water loss in grams.						Total loss in 144 hrs.	Average daily transpiration.	Area in sq. in.	Area in m.	Average transpiration per sq. m. per hr.	Gain in area in sq. m.	Area (2) ÷ by Area (1).
	May.												
	15.	16.	17.	18.	19.	20.							
1	22.	20.5	28.5	26.	28.	28.5	153.5	25.58	52.04	.02058	37.24	.01507	3.7
2	43.	39.	47.	43.	45.	42.5	259.5	43.25	66.51	.02625	68.52	.01348	2.
3	43.5	36.5	48.5	44.	46.	43.5	262.	43.6	67.69	.02665	69.65	.01807	1.9
4	31.5	26.5	34.5	36.5	43.	43.	215.	35.83	60.29	.02380	62.7	.01773	2.9
5	35.5	28.5	37.	36.5	38.	34.5	210.	35	63.77	.02520	57.8	.01416	2.2
6	22.	19.	26.	21.5	24.5	21.5	134.5	22.42	33.55	.01325	71.04	.00743	2.2
7	30.	29.5	33.	33.5	33.5	31.5	191	31.83	67.51	.02664	49.75	.01823	3.1
8	34.5	20.5	35.	30.5	37.	32.5	190.	31.65	48.97	.01935	68.15	.01098	2.3
13	18.5	20.5	23.	22.	21.	21.	126.	21.	61.12	.02418	36.22	.01323	2.5
14	29.5	34.5	42.	32.5	35.	32.5	206.	34.33	79.92	.03128	45.7	.02638	2.3
16	32.	24.5	39.5	38.	39.	36.	309.	34.83	61.32	.02420	59.99	.01584	2.6
Average								32.67	60.24	.02376	56.93	.01546	2.47

TABLE 10.—TRANSPIRATION RECORDS OF INOCULATED PLANTS IN EXPERIMENT REPORTED ON PAGE 33: PLANIMETER READINGS MADE IN SQUARE INCHES.

Inoculated on May 7.

Plant.	Water loss in grams.					Total loss in 120 hrs.	Average daily transpiration.	Area in sq. in.	Area in sq. m.	Transpiration per sq. m. per hour.
	May.									
	2.	3.	4.	5.	6.					
9	14.5	16.	15.	6.	11.5	63.	12.6	28.61	.01131	46.4
10	17.5	16.	14.5	5.5	12.5	66.	13.2	23.64	.00934	58.85
11	16	18.5	16.	6.5	12.	69.	13.8	24.16	.00955	60.2
12	9.5	9.5	9.	3.5	7.	38.5	7.7	12.53	.004958	64.73
15	28	26.5	20.	11.5	18.5	104.5	20.9	36.37	.01396	62.4
17	19.5	20.5	17.	8.	13.5	78.5	15.7	23.49	.00928	70.4
18	11.5	11.	9.5	3.5	6.	41.5	8.3	9.56	.00377	91.6
19	20.	20.	18.	10.5	14.5	83.	16.6	27.25	.01078	64.18
20	11.	13.5	11.5	4.	7.	47.	9.4	16.78	.00666	58.78
21	20.5	20.5	20.	20.	16.5	87.5	17.5	29.84	.0118	61.75
22	9	9.5	8.5	3.	6.5	36.5	7.3	11.65	.0046	66.2
Average	....	....	....	....	....	22.88	13.1	22.88	.00904	60.3

Plant.	Water loss in grams.						Total loss in 144 hrs.	Average daily transpiration.	Area in sq. in.	Area in m.	Average transpiration per sq. m. per hr.	Gain in area in sq. m.	Area (2) ÷ by Area (1).
	May.												
	15.	16.	17.	18.	19.	20.							
9	25.	23.	31.	31.	34.	31.	115	29.2	65.54	.02552	45.75	.01421	2.2
10	28.	25.5	38.5	38.5	41.	45.5	227	37.9	65.59	.02593	61.02	.01659	2.7
11	41.5	37.5	46.5	43.	46.	42.	256.5	42.7	71.24	.02815	63.25	.01860	2.9
12	26.5	21.5	29.	29.	35.5	37.	178.5	29.8	55.30	.02816	56.85	.01788	4.4
15	32.5	34.	49.5	38.5	43.	40.	237.5	39.6	97.01	.03839	43.00	.02438	2.6
17	40.	27.	42.5	39.	42.5	49.	231	38.5	70.10	.02808	57.15	.01880	2.9
18	14.	9.	15.	19.5	14.	12.	84.	14.	15.88	.00627	93.00	.00250	1.7
19	25.5	23.5	29.5	29.5	29.5	27.	162.5	27.1	69.31	.02738	41.3	.01660	2.5
20	30.	23.	29.5	30.5	35.	33.5	181.5	30.2	59.33	.02344	53.52	.01678	3.5
21	36.5	24.5	31.	29.	29.	29.	170.	28.3	59.70	.0236	50.00	.01180	2.5
22	21.5	10.	28.5	23.	27.5	24.	137.5	22.9	41.01	.01622	58.85	.01162	3.5
Average	....	....	....	....	....	....	....	30.9	60.82	.02214	58.2	.01310	2.88

DESCRIPTION OF PLATES.

Plate 1.
Diseased plant showing killing of lower leaves.

Plate 2.
Fig. 1. The disease as found in the field.
Fig. 2. Diseased spots X 5.

Plate 3.
Fig. 1. Van Tieghem cells with distilled water and nutrient glucose agar.
Fig. 2. Plants used in transpiration experiment. The pots are inside of cheese cartons which are cemented to Petri dishes with paraffin.

Plate 4.
Fig. 1. Pycnidium in the leaf, showing spores pushing out, thus making the ostiole. X 250.
Fig. 2. Test tube cultures on tomato agar and nutrient glucose agar showing spore exudation.
Fig. 3. Section of sub-stomatal chamber of leaf showing entrance of mycelium. X 1,000.

Plate 5.
Fig. 1. Pycnidum before arisal of spores showing mycelial strands running across the chamber. X 750.
Fig. 2. Magnified camera drawing showing nature of young pycnidial wall. X 750.

Plate 6.
Fig. 1. Mycelium in hanging drop culture showing arisal of secondary spores, and heavy-walled mycelium.
Fig. 2. Mycelium between the cells of the host, sending blunt, tubular haustoria into the cells. X 1,000.

Plate 7.
Fig. 1. Pycnidium on a tomato leaf, showing relation of spores and adjacent tissue to ostiole formation. X 800.
Fig. 2. Pycnidium from test tube culture showing spores masses pushing into agar. X 300.

Plate 8.
Fig. 1. Spore showing globose ends.
Fig. 2. Germinating spores producing secondary spores.
Fig. 3. Secondary spore germinating.
Fig. 4. Mycelium producing secondary spores (corn meal agar).
Fig. 5. Mycelium branching, no secondary spores (nutrient glucose agar).

Plate 9.
Fig. 1. Germinating spore (tomato agar).
Fig. 2, 4 and 5. Stages in colony formation.
Fig. 3. Spore germinating by elongation of both ends, (nutrient broth).
Fig. 6. Mycelium with secondary spores, and heavy brown threads (corn meal agar).
Fig. 7. Mycelium (nutrient glucose agar).
Fig. 8. Pycnidium formation (corn meal agar).

PLATE 1.

PLATE 2

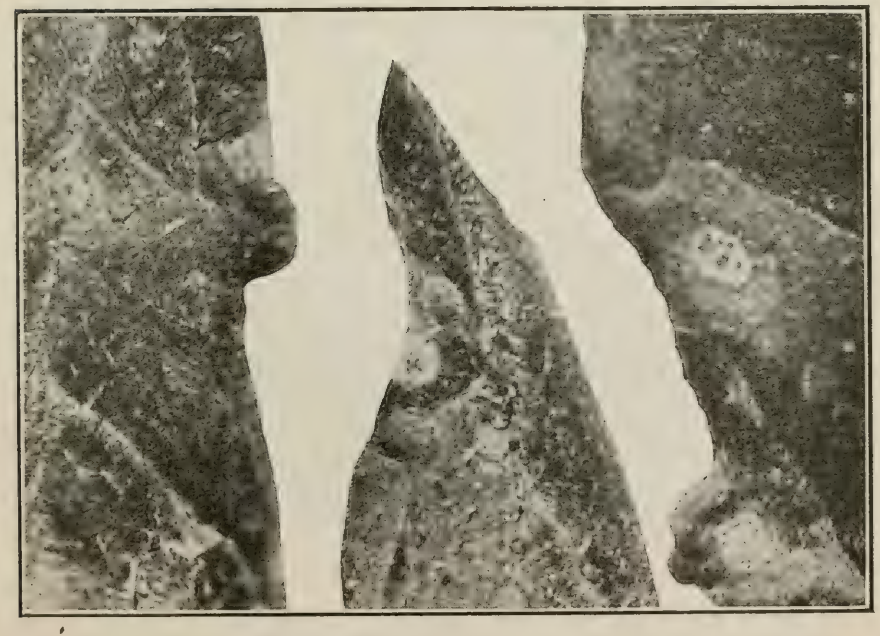


PLATE 3.

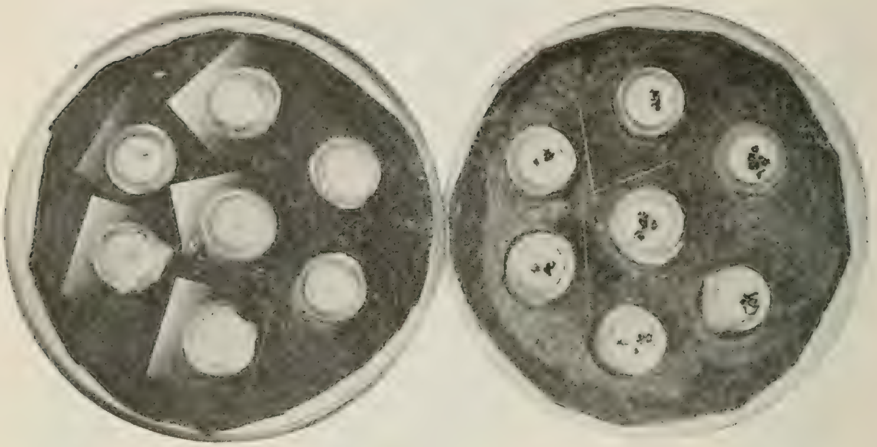


PLATE 4.

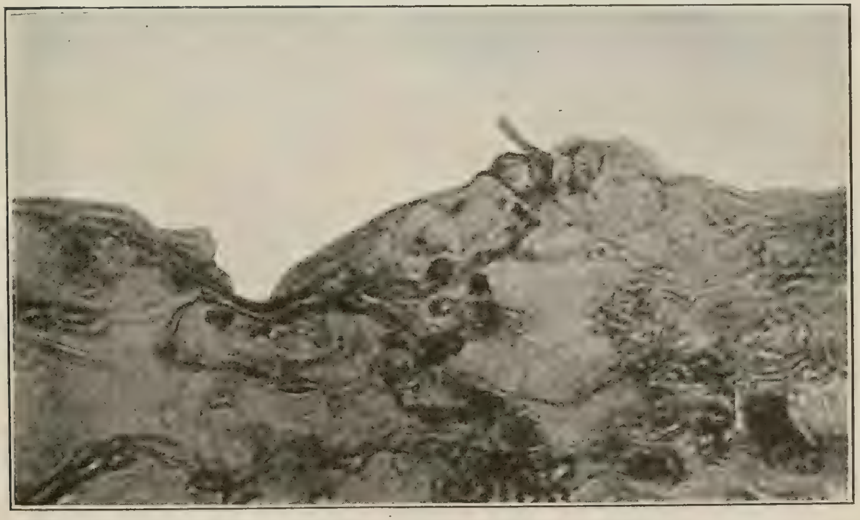


PLATE 5.

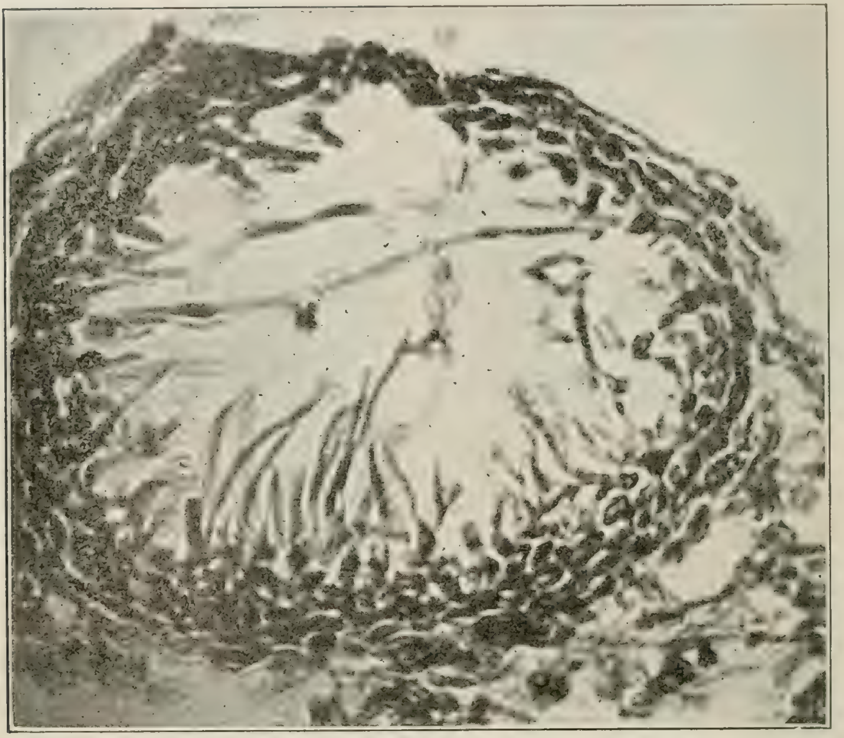


Fig 1.

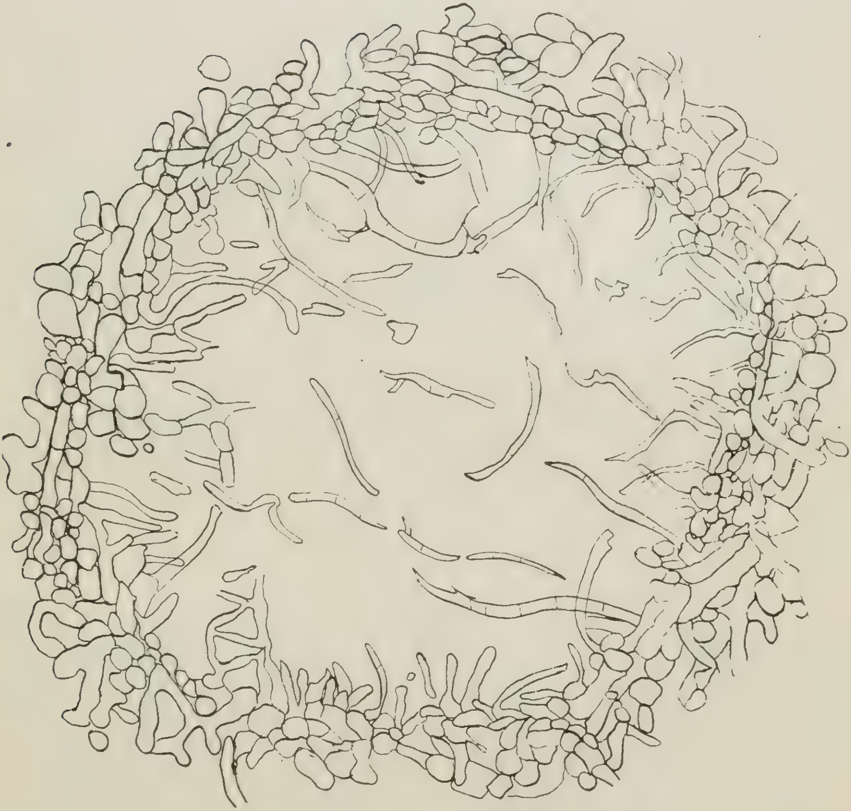
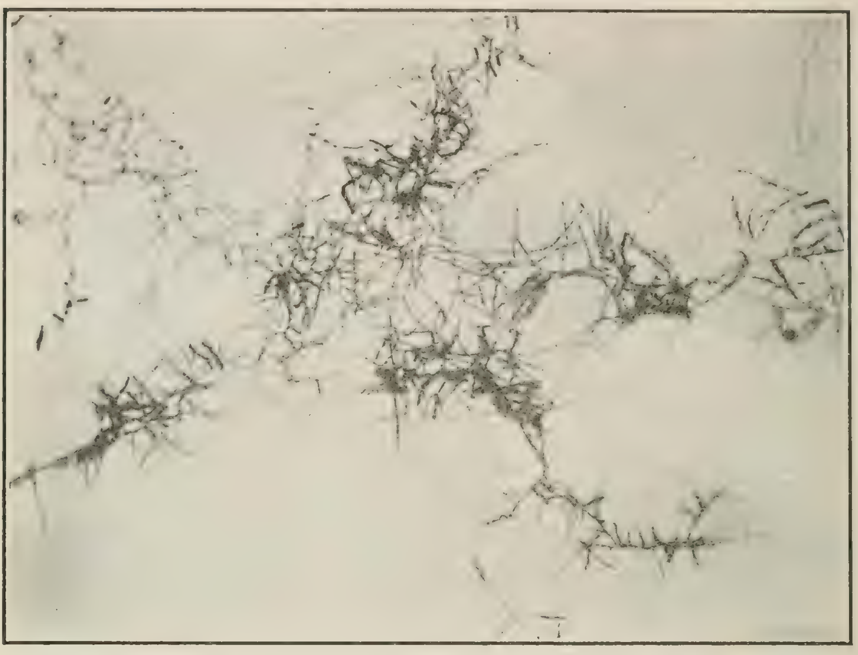


Fig 2.

PLATE 6.



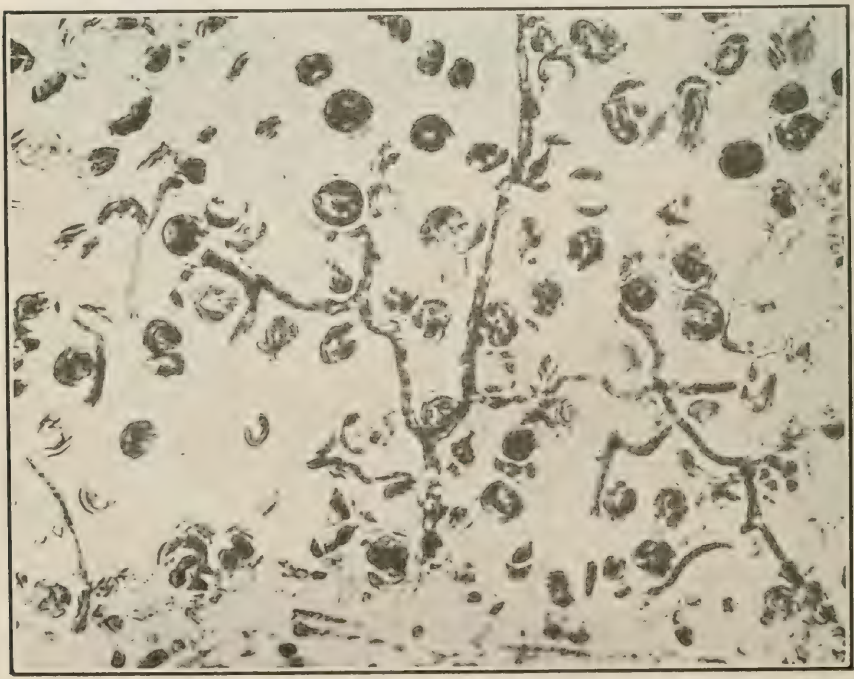
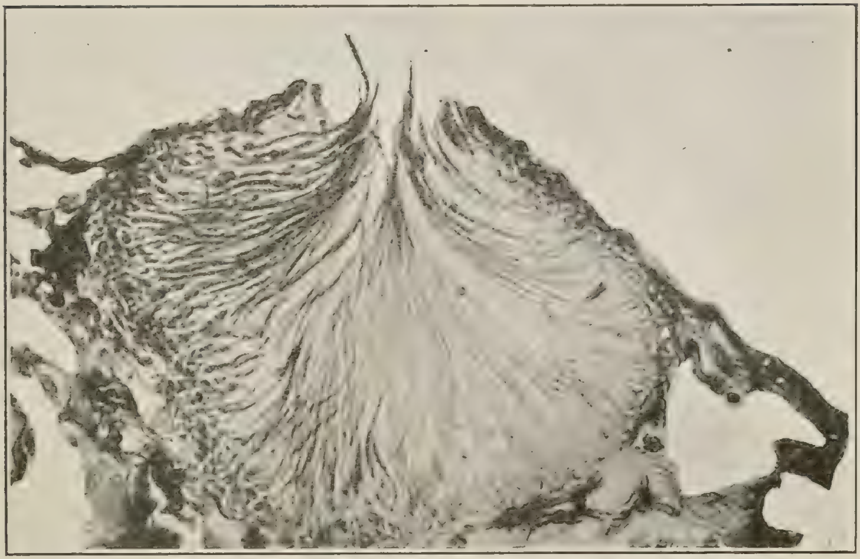


PLATE 7.



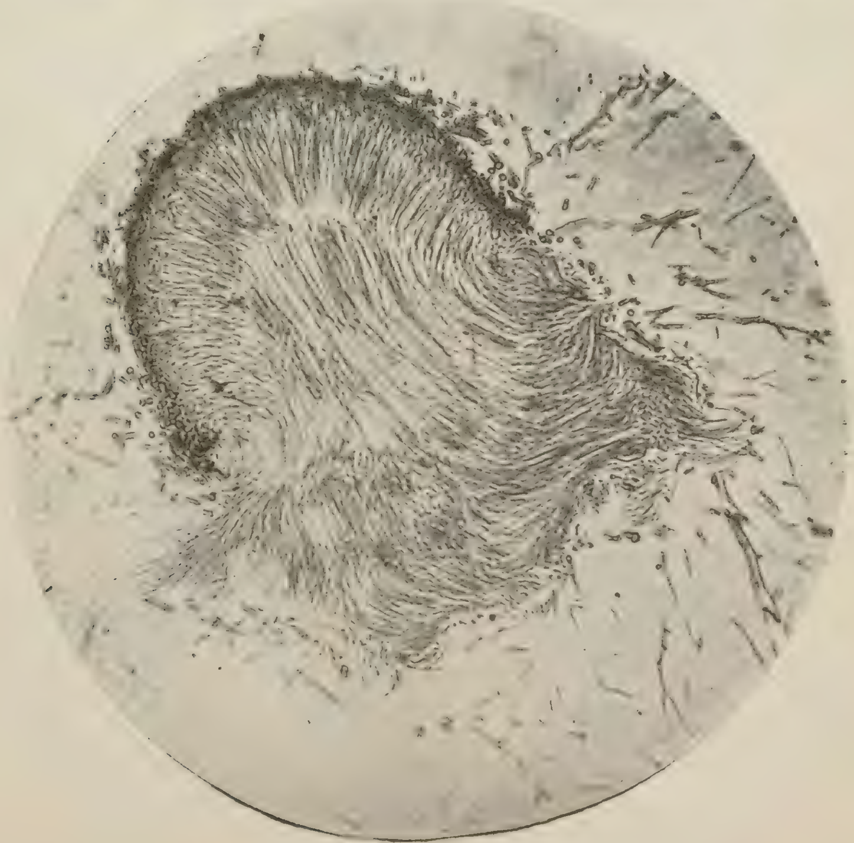


PLATE 8.

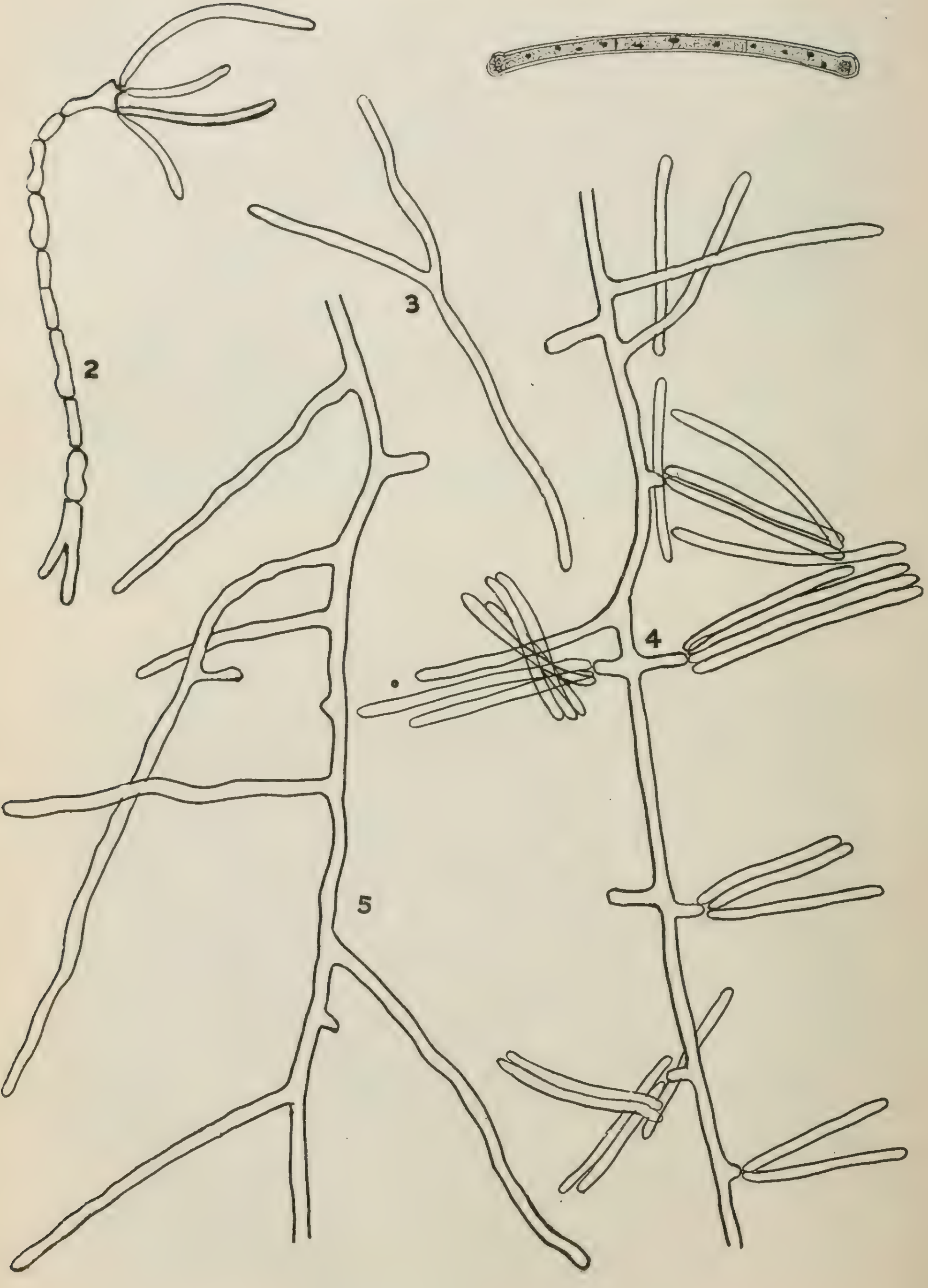
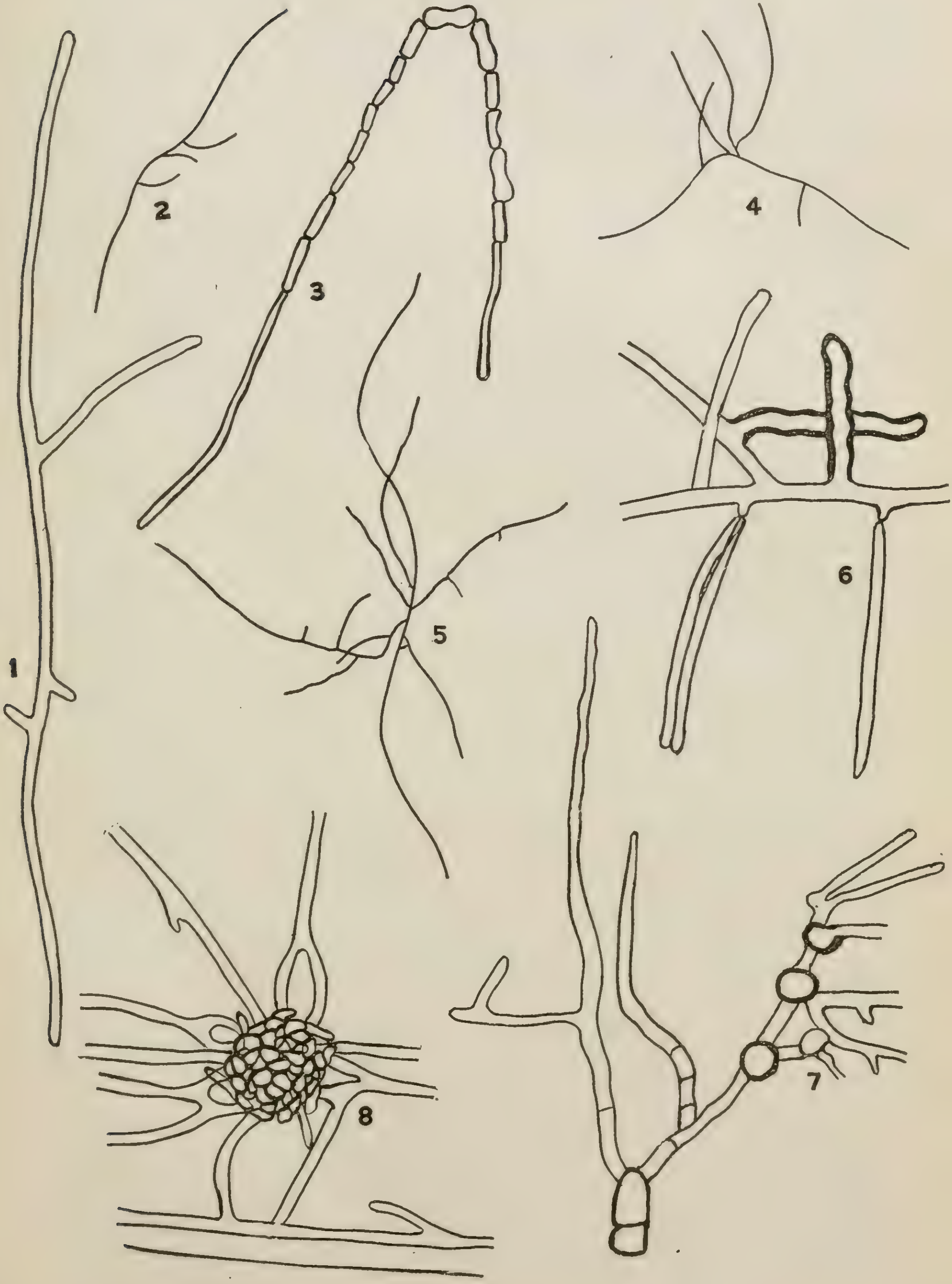


PLATE 9.



SOIL TEMPERATURE

Technical Bulletin No. 26.

BY GEORGE J. BOUYOUCOS.

INTRODUCTION.

In the fall of 1911 an investigation of the general subject of soil temperature was undertaken at this Station. Although the subject had already received a large amount of attention yet it was not considered solved, as our knowledge concerning it appeared very unsatisfactory. This is undoubtedly due to the fact that the problem is a most complex one, as the number of factors influencing it is very great. These factors may be divided into two general groups, (1) the intrinsic and (2) the external. The intrinsic factors are those contained by the soil and comprise the specific heat, heat conductivity, thermal absorption and radiation, specific gravity, texture, structure, moisture content, salt content, topographic position, nature of surface, etc. The external factors include the meteorological elements, chief of which are the air temperature, sunshine, wind velocity, barometric pressure, precipitation, dew point, humidity, etc. The intrinsic factors vary with the different kinds of soil and tend to exert a temporary or permanent controlling influence upon the soil temperature. They are acted upon by the external factors which cause the soil temperature to fluctuate as they themselves vary. Inequality in temperature, therefore, in different kinds of soil for any particular day will depend upon their intrinsic factors, but variation in temperature in these same soils for succeeding days or seasons will depend upon the external factors. Both of these groups of factors may be subdivided into two parts, one part tending to take up or import heat to the soil system and thereby raise its temperature, and the other part tending to give up or take away heat from the same soil system and thereby lower its temperature. These opposing factors are in operation practically all the time. The temperature of a soil, therefore, under field conditions, is the resultant of all these variables and contesting forces.

Most of the previous investigators usually studied only one or two of the intrinsic factors influencing or controlling the soil temperature and then, as a very general rule, deducted general conclusions therefrom as to the importance and controlling effect of these factors upon the soil temperature. There appears to be no one investigator who attacked the subject thoroughly and systematically from all standpoints. As a result wrong conclusions have been drawn, and are being disseminated at present, as to the importance and controlling effect of some of the intrinsic factors upon soil temperature, which have led to erroneous beliefs concerning the difference in temperature in the different classes of soil.

In undertaking an investigation of the subject, therefore, it was resolved to study it from all standpoints as systematically and thoroughly as possible. The plan finally decided upon consisted (1) of studying individually or in combination most of the chief intrinsic factors affecting the soil temperature, under controlled conditions, (2) investigating the influence of these various important factors upon soil temperature under field conditions and (3) ascertaining the relationship between the soil temperature and the different meteorological elements or external factors.

In the report of 1913[1] there were embodied the results of the completed laboratory experiments on the intrinsic factors influencing soil temperature and one year's data of the field experiments. The field experiments have been continued up to the present time, or for four years, and it is the purpose of this bulletin to present the additional data obtained from these experiments and also the final conclusion that might be deducted from the entire investigation.

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[1] Technical Bul. 17, Mich. Expt. Sta. 1913.

BRIEF REVIEW OF PREVIOUS REPORT.

The investigation on the specific heat of soils showed that the magnitude of this property was about the same for all types of soil, namely gravel, sand, humus loam, clay and peat; this being true both by equal weight as well as by equal volume. By equal weight the magnitude of the value was about 0.200°C and by equal volume about 0.500°C. The specific heat of peat was only about one-half as great as that given to it by previous investigators.

It was concluded that in view of this remarkable equality of the specific heat of the diverse types of soil, this factor exercised practically no influence in causing and maintaining a difference in temperature in these various soils.

Since, however, these diverse types of soil contain different amounts of water, on account of the marked variation in their water-holding capacity, and water possesses five times as great specific heat as the dry soils by equal weight or two times as great by equal volume and its latent heat of evaporation and heat of fusion are tremendously high, it was concluded that the water content of the soil is one of the chief intrinsic factors which might cause a variation in the temperature of these various classes of soil.

The phenomen of heat conductivity was measured in different types of soil, (1) in their dry condition, (2) in their natural state under laboratory conditions and (3) in their natural state under field conditions. It was found that in all these three states the magnitude of heat transference was markedly different in the various types of soil but the order was always the same, namely, gravel manifested the highest heat-transmitting power followed in order by sand, clay, loam and peat, respectively.

It was concluded, however, that even though these diverse classes of soil possess markedly different abilities to propogate heat, yet this factor of heat conductivity is only of secondary and not of primary importance in the control and variation of their temperature. In other words heat conductivity is not a dominant factor and the small variation in average temperature that it would cause in the different types of soil under normal conditions is neutralized or offset by other contrary factors and consequently as an agent itself it cannot cause a permanent variation in average temperature in those soils which possess it in different degrees. Or if it is a dominant factor it opposes some other contrary factor and causes those soils which possess it to the highest degree to have the same average temperature as those that contain it in the least extent.

Under special circumstances, however, such as when a mulch is formed on a cultivated soil heat conductivity might exert a slight predominating and controlling influence on the soil temperature. In such a case, however, it is the thin layer of dry soil formed at the surface that plays the leading role rather than the entire tilled layer.

Again in such abnormal soil as peat heat conductivity might predominate and cause a slightly greater cooling at the upper one or two inch depths than in the mineral soils.

The radiating power of the various types of soil was also investigated. It was discovered that color had no effect upon radiation, which is contrary to the popular belief,—but it had a tremendous influence upon the absorption of the solar energy. The various classes of soil radiated slightly differently when in the dry condition, about the same and slightly more when well moistened and that a dry surface or mulch reduced somewhat the amount of radiation. In the dry state sand exhibited the highest radiating power, followed in order by gravel, clay, loam, and peat, respectively. The water, however, manifested far greater radiating capacity than any soil either in the dry or moist condition. The deduction was made that as far as radiation is concerned all the diverse classes of soil lose heat practically to the same extent and that the difference in minimum temperature that is noted in them in the morning or during a period of sudden cold weather is attributed to the difference in their total specific heat.

It was discovered that a high concentration of soil solution tended to raise the soil temperature during the insolation by reducing the amount of evaporation and that during the winter it diminished the lowering of the freezing point and hastened the rate of thawing.

The study on the effect of decomposition of manure on the temperature of soil showed that large applications of this material in the fresh state could raise the soil temperature appreciably, but considering the small amounts that are commonly applied to the soil under field conditions and that a rather high temperature is required for the decomposition process, it was concluded that the amount of heat gained by the soil from this source is absolutely insignificant.

The field studies on the effect of cultivation, noncultivation, and sod upon soil temperatures indicated that during the winter the temperature of the soil under these three cultural conditions was about the same with a slightly higher degree in favor of the sod. In the spring all the soils thawed practically simultaneously and maintained identical average temperature until the vegetation in the sod plot commenced to grow when its temperature began to be lower than that of the other plots, and continued to be smaller until in the fall when the order was reversed. The temperature of the cultivated and uncultivated plots was the same throughout the year except during the spring and summer months when the uncultivated plot had a slightly higher average temperature than the cultivated.

The results from the investigation on the influence of organic matter on the soil temperature showed that those soils containing 1.8, 2.01, 3.32, 5.47; and 6.95% of organic matter thawed practically simultaneously and peat several days later. After complete thawing, however, the peat and the soil containing the least percentage of organic matter and which had a white surface, reached and maintained an appreciably lower average temperature than the other soils throughout the spring and summer months up until in the fall and then this difference disappeared and all the soils began to have approximately equal degrees of temperature with peat being slightly warmer.

The temperature of the five different types of soil, namely, gravel, sand, humus loam, clay and peat, whose many intrinsic factors were investigated in the laboratory as already discussed, was measured daily throughout a whole year under field conditions, at three different depths. The data yielded by this investigation showed that when all these different types of soil were covered with a thin layer of sand their average temperature was practically the same throughout the year except in the early spring when they were undergoing thawing. At this period their average temperature was markedly different, especially between that of the mineral types and peat, due to their different rate of thawing. After they were all completely thawed, however, their average temperature reached about the same degree and remained practically the same until the next thawing period. Unlike in the spring, in the fall they all cooled at about the same rate. The only other time that their average temperature varied appreciably besides in the spring was whenever there occurred rapid changes in the air temperature, but they would soon reestablish their equilibrium. The amplitude of temperature of course, was very different in them. It was greatest in sand and gravel, followed in order by clay, loam, and peat, respectively.

The results of the last investigation, therefore, indicated that the average temperature of the diverse classes of soil does not vary as much as is popularly believed or as one would think, in view of the great variation of the intrinsic factors in them.

ADDITIONAL EXPERIMENTAL DATA ON THE TEMPERATURE OF DIFFERENT TYPES OF SOIL AT DIFFERENT DEPTHS AND UNDER DIFFERENT SURFACE CONDITIONS FOR 1913, 1914, AND 1915.[2]

PLAN OF THE EXPERIMENT.

As described in the first report this investigation was prepared by making a long trench a little over three feet wide on a smooth and slightly rolling piece of ground, covering the bottom with a thin layer of a sandy soil so as to be uniform throughout, then placing into this trench, about one foot apart, wooden boxes 3x3x3 feet without bottom or top, and then filling these boxes with five different types of soil, namely, gravel, sand, clay, humus loam, and peat. After they were flooded with water several times and a certain length of period was allowed to elapse in order that they might settle, a study of their temperature was commenced. Their temperature was measured at three different depths, 6, 12, and 18, or 2, 4, and 6 inches, three times a day, usually at about 7 A. M. 12 M. and 6 P. M. every day throughout the year except Sundays, by means of electric resistance thermometers. These instruments consisted of resistance bulbs and 35 feet wire leads. The leads were incased in lead pipe so as to keep them dry and well insulated. The ends of these leads were run into a small house specially constructed for the purpose. In this house there was kept, on a permanent stand, a balance indicator upon which the temperature was read.

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[2] The author wishes to express his deepest gratitude and indebtedness to Mr. M. Wolkoff, a graduate student, for his most loyal and excellent intelligent support in the conduct of the following experiments and in the preparation of the many laborious tables.

During the first year, from Dec. 1, 1911 to Nov. 30, 1912, the surface of all the five different types of soil was covered with a very thin layer of sand in order to eliminate their differential factor of color. The temperature during this period was also measured by an indicator graduated to only 1°F.

During the second year, from December 1, 1912 to November 30, 1913, the thin layer of sand was removed from the surface of all the soils and consequently their natural surface was exposed to the atmosphere and allowed to play its role. Beginning with this year also the old balance indicator was replaced by a new one which was graduated to 0.5°F and thus more sensitive than the first.

In the third year, from December 1, 1913 to November 30, 1914, all the soils were again covered by a thin layer of sand.

At the beginning of the fourth year, however, from December 1, 1914 to November 30, 1915, the surfaces of all the soils were again uncovered, and the thermometers were removed from the 6, 12 and 18 inch depths at which they had remained from the beginning of the experiment, and placed at 2, 4, and 6 inch depths, respectively. During the warm part of this year the surface temperature was also taken by means of mercury thermometers having extremely small bulbs.

It was stated above that the temperature records were taken at 7 A. M., 12 M. and 6 P. M. These periods, however, were changed somewhat during the year in order to obtain as true an average and range of temperature as possible. During the warm part of the year, when the sun rose early in the morning, the temperature records were taken at about 6 A. M., 1 P. M. and 5 P. M., while during the cold part of the year they were taken at about 7 A. M., 12 M. and 6 P. M. The daily average temperature, therefore, is composed of these three diurnal readings, and the daily amplitude, the difference between the highest and lowest temperature recorded during the day.

Even though the temperature was recorded three times a day it cannot be claimed, however, that it gives the absolute average and range of temperature for all depths and for all soils. This is at once obvious from the fact that the real maximum and minimum temperatures at the various depths of the same and of different soils are attained at entirely different periods of the day. The three diurnal records, however, do give a very close approximation of the true daily average and fluctuation of temperature for all soils and for all depths. Furthermore, since these three diurnal records have been taken almost every day for four years the average for the month, season or year is exceedingly close, if not exactly, the true average and range of temperature.

As already mentioned the previous report[3], contained all the data for the first year. In the present report will be presented the results for the following three years, or from December 1, 1912, to November 30, 1915.

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[3] Technical Bul. 17, Mich. Expt. Sta., 1913.

THE DAILY AND MONTHLY AVERAGE TEMPERATURE FOR 1913, 1914 AND 1815.

BEGINNING WITH THE SECOND YEAR.

TABLE 1.—AVERAGE TEMPERATURES OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, DECEMBER, 1912 (a)

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2..........	42.77	42.10	41.17	42.77	42.17	41.60	40.23	39.23	40.10	41.50	39.70	40.03	37.53	37.63	40.63
3..........	37.20	38.73	41.13	36.90	39.10	41.53	37.63	39.93	41.37	37.77	40.10	41.33	37.73	38.50	40.83
4..........	37.90	38.43	39.77	37.73	38.43	40.03	37.03	38.67	40.50	37.50	38.77	40.00	36.47	38.23	40.67
5..........	38.10	38.53	39.83	37.87	38.50	40.13	37.03	38.63	40.37	37.43	38.70	39.87	36.47	37.97	40.43
6..........	40.70	41.93	42.00	40.57	41.70	42.23	40.50	40.87	41.27	40.57	41.10	41.20	39.43	38.77	40.97
7..........	35.50	37.43	40.13	36.00	37.57	40.43	36.43	39.40	41.23	36.40	39.30	40.80	37.57	38.87	40.87
9..........	33.00	34.90	38.10	33.47	35.33	38.50	34.10	37.27	39.63	33.87	36.97	38.77	35.30	38.07	40.80
10..........	32.20	34.10	37.10	32.60	34.50	37.70	33.33	36.43	38.80	33.07	36.17	37.97	34.53	37.30	39.77
11..........	32.40	34.07	36.90	32.43	34.50	37.43	33.10	35.97	38.27	32.90	35.73	37.47	33.87	36.67	39.60
12..........	30.67	32.90	36.13	30.83	33.40	36.90	32.53	35.57	37.87	32.20	35.27	37.07	33.40	36.20	38.90
13..........	29.87	31.90	35.27	30.00	32.47	36.00	31.50	34.73	37.17	31.23	34.40	36.27	32.63	35.40	38.43
14..........	29.97	31.80	34.70	29.83	32.10	35.53	30.93	34.07	36.60	30.93	33.77	35.67	32.27	34.83	37.93
16..........	30.93	32.00	34.77	31.10	32.83	35.50	31.23	33.87	36.20	31.13	33.67	35.33	32.13	34.50	37.27
17..........	31.27	32.50	34.90	32.00	33.27	35.67	31.37	33.97	36.30	31.50	33.80	35.33	32.17	34.40	37.20
18..........	32.37	33.43	35.77	33.30	34.43	36.47	32.10	34.63	36.73	32.30	34.53	35.90	32.80	34.83	37.57
19..........	32.63	33.73	35.83	33.13	34.70	36.63	32.27	34.80	36.73	32.60	34.83	36.23	32.83	34.87	37.57
20..........	32.87	34.03	35.87	33.00	34.37	36.53	32.23	34.63	36.63	32.63	34.70	36.03	32.83	34.70	37.37
21..........	33.00	34.00	35.83	32.97	34.47	36.40	32.33	34.77	36.50	32.77	34.83	35.93	32.87	34.73	37.27
23..........	31.93	33.03	35.23	31.60	33.33	35.87	31.67	34.13	35.87	32.07	34.27	35.53	32.13	33.97	36.60
24..........	31.40	32.73	34.73	31.23	32.87	35.10	31.13	33.53	35.63	31.37	33.53	35.00	31.53	33.60	36.17
26..........	31.80	33.07	35.07	31.57	33.00	35.50	31.43	34.00	35.80	31.70	33.97	35.27	32.03	34.00	36.50
27..........	32.43	33.50	35.30	32.03	33.53	35.83	31.97	34.30	36.17	32.33	34.30	35.73	32.43	34.30	36.93
28..........	31.53	32.83	34.90	31.50	33.00	35.27	31.43	33.77	35.60	31.70	33.90	35.27	32.00	33.83	36.47
30..........	31.93	33.07	34.97	32.10	33.07	35.23	31.43	33.70	35.57	31.87	33.87	35.07	31.90	33.63	36.23
31..........	31.80	32.93	34.73	31.73	33.03	35.03	31.27	33.50	35.37	31.80	33.67	34.97	31.70	33.47	36.10
Monthly average..	33.45	34.71	36.81	33.53	35.03	37.32	33.45	35.77	37.69	33.65	35.75	37.12	33.86	35.73	38.36

(a) Unless otherwise stated the temperature figures in all the tables are expressed in Fahrenheit degrees.

TABLE 2.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JANUARY, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	31.63	32.73	34.23	31.53	32.87	34.83	31.13	33.17	34.97	31.57	33.37	34.73	31.47	33.13	35.80
2..........	31.77	32.83	34.30	31.67	32.93	34.97	31.13	33.23	35.00	31.63	33.40	34.70	31.47	33.23	35.80
3..........	32.40	33.23	34.97	32.17	33.53	35.37	31.57	33.67	35.30	32.27	34.00	35.07	31.87	33.73	36.10
4..........	32.43	33.30	34.90	32.17	33.50	35.33	31.83	33.80	35.37	32.20	34.03	35.10	31.97	33.57	35.93
6..........	31.57	32.70	34.43	31.43	32.87	34.80	31.10	33.23	35.10	31.43	33.43	34.80	31.47	33.20	35.90
7..........	32.43	33.33	35.03	32.50	33.50	35.37	31.63	33.90	35.60	32.33	34.10	35.40	32.17	34.00	36.47
8..........	32.70	33.60	35.10	32.50	33.80	35.70	31.80	34.10	35.80	32.40	34.20	35.10	32.20	34.10	36.50
9..........	31.80	32.95	34.35	31.65	32.90	34.85	31.20	33.30	34.95	31.60	33.30	34.75	31.50	32.80	35.70
10..........	32.03	33.00	34.53	31.83	32.97	34.93	31.53	33.47	35.10	31.87	33.43	34.67	31.63	33.30	35.83
11..........	32.13	33.07	34.43	31.80	33.03	34.97	31.30	33.30	34.97	31.83	33.40	34.67	31.70	33.23	35.67
13..........	32.57	33.53	34.90	32.13	33.53	35.20	31.60	33.83	35.13	32.10	33.83	34.93	31.90	33.47	35.97
14..........	32.50	33.40	34.93	32.23	33.50	35.20	31.50	33.60	35.07	32.00	33.77	35.07	32.10	33.63	35.83
15..........	32.70	33.40	34.93	32.20	33.53	35.07	31.47	33.63	35.13	32.03	33.83	34.83	31.73	33.27	35.73
16..........	32.63	33.53	34.87	32.10	32.97	34.23	31.80	33.77	35.17	32.10	33.83	34.97	31.83	33.67	35.87
17..........	32.33	33.37	34.90	32.07	33.97	34.77	31.90	33.70	35.03	32.20	33.90	34.87	31.90	33.33	35.73
18..........	32.27	33.80	34.83	32.17	33.63	34.97	31.87	33.60	35.17	32.17	34.00	35.00	32.00	33.30	35.60
20..........	32.97	33.93	35.03	33.03	34.03	35.57	32.13	33.87	35.50	32.73	34.10	35.27	32.13	33.53	35.90
21..........	33.43	34.13	35.40	33.23	34.23	35.60	32.27	34.10	35.60	32.87	34.30	35.33	32.13	33.50	35.97
22..........	33.27	34.17	35.33	33.17	34.23	35.50	31.97	33.90	35.40	32.80	34.07	35.10	32.03	33.47	35.63
23..........	33.17	34.10	35.37	33.03	34.10	35.50	31.97	33.83	35.20	32.80	34.17	35.13	32.00	33.30	35.70
24..........	33.13	34.00	35.27	33.00	34.00	35.30	32.00	33.87	35.20	32.87	34.23	35.17	32.03	33.37	35.70
25..........	33.27	34.10	35.30	33.10	34.07	35.53	32.07	33.97	35.33	32.93	34.20	35.23	32.03	33.37	35.80
27..........	33.10	33.90	35.13	32.83	33.93	35.13	31.90	33.93	35.07	32.80	34.00	35.00	31.80	33.07	35.53
23..........	32.50	33.43	34.93	31.87	33.37	35.03	31.93	33.80	35.07	32.63	34.03	35.03	31.90	33.17	35.53
29..........	31.13	32.90	34.73	29.70	32.67	34.80	31.47	33.83	35.13	31.93	33.90	34.90	30.97	33.23	35.63
30..........	31.03	32.20	34.03	30.67	32.13	34.20	31.10	33.17	34.77	31.33	33.20	34.27	30.87	32.87	35.07
31..........	31.67	32.50	33.93	31.30	32.17	33.90	31.13	33.20	34.80	31.70	33.17	34.30	31.30	32.93	35.23
Average ..	32.39	33.38	34.82	32.11	33.41	35.06	31.64	33.66	35.18	32.19	33.82	34.94	31.78	33.36	35.78

TABLE 3.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, FEBRUARY, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	29.26	32.23	34.16	30.86	32.80	34.30	31.00	33.23	34.90	31.26	33.26	34.50	29.63	33.10	35.23
3..........	28.63	30.36	33.13	27.83	30.93	33.53	29.26	32.63	34.20	29.30	32.46	33.80	28.20	32.40	35.00
4..........	27.66	30.10	33.16	26.00	30.63	33.70	28.96	32.76	34.30	29.13	32.53	33.86	27.36	32.80	35.06
5..........	24.33	27.96	32.56	21.30	28.23	33.10	26.26	32.00	33.86	26.66	31.86	33.16	23.73	32.03	34.56
6..........	22.96	26.26	31.90	19.86	26.63	32.73	24.66	31.46	33.60	25.06	31.36	33.00	21.80	31.73	34.40
7..........	25.86	27.70	31.73	23.86	28.00	32.76	25.93	31.30	33.43	26.20	30.96	32.83	24.13	31.63	34.46
8..........	26.70	28.20	31.20	25.83	28.73	32.06	26.40	30.83	33.03	26.40	30.16	32.30	25.46	31.16	34.00
10..........	25.30	27.20	31.20	24.06	28.03	31.90	25.80	30.40	32.86	26.06	29.96	31.96	24.16	30.56	33.66
11..........	28.20	29.06	30.66	28.40	29.50	31.20	27.46	29.86	31.76	27.93	29.73	31.26	27.80	30.16	33.10
12..........	24.30	26.86	30.96	22.10	27.46	31.70	25.36	30.13	32.33	25.70	29.76	31.56	23.03	29.86	33.40
13..........	22.43	25.20	30.46	19.60	25.96	30.90	23.30	29.43	32.26	23.93	28.93	31.36	20.50	28.30	33.06
14..........	24.93	26.53	30.23	23.73	27.23	30.90	24.80	29.03	32.10	25.10	28.53	31.03	23.50	28.03	32.70
15..........	29.00	29.63	30.66	29.13	29.93	31.00	27.90	29.60	31.43	28.80	29.23	30.76	28.13	29.16	32.40
17..........	29.30	30.03	31.10	29.06	30.03	31.20	28.46	30.03	31.53	28.66	29.90	30.93	28.40	29.73	32.30
18..........	28.23	29.27	31.03	27.57	29.20	31.23	27.87	29.97	31.50	28.37	29.97	30.93	27.17	29.63	32.27
19..........	30.57	30.70	31.10	30.70	31.07	31.43	29.17	30.07	31.50	29.33	29.83	31.07	30.10	30.17	32.50
20..........	31.57	31.57	31.47	31.37	31.60	31.63	29.93	30.97	31.70	30.40	30.73	31.23	30.60	30.53	32.33
21..........	32.17	32.57	32.20	31.97	32.30	32.47	30.97	31.57	32.53	31.57	31.43	32.00	31.43	31.20	32.97
22..........	31.83	31.93	32.03	31.63	31.93	31.93	30.70	31.20	32.13	31.27	31.23	31.70	31.27	30.97	32.70
24..........	32.00	32.00	32.05	31.75	32.00	32.15	31.00	31.30	32.05	31.65	31.65	31.85	31.35	31.15	32.85
25..........	31.57	31.83	31.67	31.43	31.73	31.97	30.67	31.07	31.87	30.90	31.37	31.60	31.13	31.00	32.67
26..........	31.63	31.73	31.77	31.30	31.60	31.97	30.47	31.10	31.77	30.63	31.23	31.63	31.23	31.03	32.50
27..........	31.57	31.77	31.97	31.53	31.83	32.33	30.63	31.30	32.10	30.90	31.13	31.70	31.33	31.13	32.97
28..........	31.73	31.97	31.83	31.47	31.80	32.10	30.47	31.20	31.90	30.83	31.27	31.70	31.10	31.00	32.33
Average...	**28.40**	**29.70**	**31.67**	**28.01**	**29.96**	**32.09**	**28.23**	**30.94**	**32.53**	**28.59**	**30.77**	**31.99**	**27.61**	**30.77**	**33.31**

TABLE 4.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, MARCH, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18
1..........	31.47	31.70	31.80	31.43	31.67	32.13	30.17	31.07	31.77	30.57	31.27	31.47	30.90	30.87	32.23
3..........	31.60	31.77	31.87	30.87	31.63	32.17	30.00	31.10	31.77	30.27	31.13	31.57	30.13	30.87	32.33
4..........	31.77	31.93	32.20	31.17	31.80	32.43	30.47	31.40	32.23	30.87	31.47	31.90	30.53	31.07	32.70
5..........	31.77	32.10	32.33	30.87	31.77	32.60	30.13	31.23	32.00	30.70	31.30	31.77	30.13	30.93	32.57
6..........	31.60	31.87	32.20	31.27	31.70	32.70	30.07	31.20	31.97	30.43	31.33	31.77	30.03	30.83	32.63
7..........	31.70	32.00	32.43	30.70	31.70	32.70	30.00	31.20	32.10	30.40	31.53	32.03	29.33	30.93	32.73
8..........	31.47	32.00	32.50	30.47	31.53	32.70	29.93	31.27	32.13	30.20	31.37	31.97	28.93	30.80	32.83
10..........	31.70	32.03	32.63	31.60	32.00	32.47	30.60	31.27	32.17	31.20	31.57	31.93	30.97	31.07	32.77
11..........	31.73	32.00	32.50	31.57	31.87	32.40	30.53	31.33	32.30	31.40	31.70	32.10	31.23	31.07	32.83
12..........	32.33	32.53	33.00	32.03	32.40	32.87	31.07	31.83	32.77	31.63	32.00	32.50	31.70	31.50	33.10
13..........	32.30	32.60	32.90	31.90	32.27	32.87	31.10	31.70	32.60	31.80	31.93	32.63	31.73	31.43	32.97
15..........	32.90	32.50	32.97	32.57	32.30	33.03	31.73	31.90	32.53	32.50	32.17	32.50	32.17	31.70	33.13
17..........	31.77	32.43	32.90	31.53	32.07	32.97	31.63	31.80	32.57	32.17	32.07	32.43	32.10	31.63	33.00
18..........	32.07	32.23	32.77	32.17	32.00	32.80	31.43	31.57	32.23	31.97	31.87	32.10	31.77	31.33	32.77
19..........	38.87	33.80	33.00	39.37	33.70	33.03	32.67	31.50	32.27	33.43	32.13	32.43	32.00	31.53	32.93
20..........	43.27	37.90	35.03	43.67	37.90	35.30	36.13	31.93	32.70	37.93	32.27	32.70	32.10	31.63	33.03
21..........	36.37	36.34	35.70	36.47	36.27	35.80	33.43	32.03	32.77	34.87	32.33	32.77	32.20	31.90	33.27
22..........	33.73	34.03	34.50	33.70	34.13	34.57	32.07	32.10	32.93	33.13	32.37	32.80	32.27	31.90	33.23
24..........	46.57	39.80	35.83	46.17	38.77	35.73	41.23	31.63	32.37	42.20	32.00	32.60	31.93	31.60	33.17
25..........	35.20	37.40	37.60	35.07	37.33	37.37	33.00	31.90	32.90	34.83	32.63	32.73	31.97	31.70	33.13
26..........	32.83	34.87	35.73	32.47	34.73	35.67	31.40	31.53	32.80	32.40	32.90	33.17	31.63	31.20	32.87
27..........	32.83	34.33	35.27	32.50	34.17	35.30	31.50	31.67	32.93	32.47	33.03	33.47	31.83	31.40	33.07
28..........	32.77	33.97	34.90	32.33	33.87	34.87	31.40	31.70	32.93	32.53	33.17	33.53	31.73	31.50	33.23
29..........	32.67	33.50	34.47	32.07	33.37	34.37	31.03	31.97	33.10	32.70	33.60	33.87	32.03	31.73	33.37
31..........	42.75	39.70	37.75	42.93	39.13	37.10	39.67	31.17	32.70	41.17	37.03	35.60	31.83	31.07	32.87
Average...	**34.16**	**33.81**	**33.78**	**33.88**	**33.60**	**33.84**	**32.10**	**31.56**	**32.46**	**32.95**	**32.25**	**32.57**	**31.33**	**31.33**	**32.91**

TABLE 5.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, APRIL, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	43.97	40.30	39.03	43.87	39.80	38.97	39.00	32.97	34.67	40.83	38.63	37.77	32.53	31.97	34.00
2..........	40.70	40.40	39.63	40.17	39.93	39.30	38.57	37.20	36.27	39.43	38.90	37.97	32.47	32.00	33.83
3..........	45.77	41.23	39.90	45.23	40.60	39.80	42.93	38.77	37.90	42.77	39.03	38.20	33.00	31.80	33.97
4..........	50.67	46.97	42.90	49.97	46.03	42.67	49.97	42.97	39.67	49.53	43.13	40.67	34.90	32.20	34.40
5..........	40.47	41.70	42.20	40.57	41.77	42.30	40.33	42.43	40.97	40.57	42.33	41.67	33.10	32.13	34.77
7..........	39.97	39.97	40.37	40.10	40.20	40.43	38.07	39.70	39.80	38.03	39.37	39.60	33.13	32.00	35.20
8..........	42.00	40.00	39.97	41.97	39.70	40.20	38.97	39.37	39.57	38.60	38.90	39.43	32.97	31 90	35.43
9..........	40.27	40.00	40.23	40.10	39.87	39.87	37.53	39.20	39.07	38.23	39.23	38.97	32.77	31.67	35 10
10..........	41.90	40.30	40.10	41.63	40.23	40.20	39.87	39.13	39.17	40.27	39.17	39.07	33.27	31.83	35 10
11..........	43.10	42.37	41.23	42.97	42.13	41.13	42.60	40.87	39.63	42.77	41.00	40.07	35.00	31.97	35.50
12..........	40.73	41.13	41.00	40.30	40.93	40.93	40.57	40.87	40.20	40.87	41.00	40.50	34.23	32.00	35.43
14..........	46.37	43.17	42.17	46.40	42.73	42.03	43.47	41.67	40.87	43.00	41.53	41.20	35.07	31.97	36.17
15..........	48.23	43.50	42.43	48.00	43.10	42.27	44.40	42.03	41.13	43.63	41.80	41.60	35.57	32.37	36.43
16..........	52.00	46.23	43.70	51.03	45.57	43.53	47.70	43.23	41.43	46.93	43.30	42.03	36.63	32.20	36.73
17..........	53.03	47.63	45.27	51.67	46.50	44.63	48.70	44.50	42.93	48.40	44.67	43.37	37.33	32.57	37.30
18..........	57.87	51.00	46.73	56.17	49.50	46.20	53.47	46.43	43.83	52.87	46.80	44.77	39.73	32.73	37.30
19..........	52.40	50.00	48.00	51.60	49.13	47.40	49.57	47.80	45.07	49.77	48.03	46.47	40.57	33.10	38.00
21..........	48.60	46.27	46.07	47.47	45.87	45.67	45 77	45.73	44.97	45.63	45.80	45.37	41.00	39.37	41.47
22..........	55.47	49.13	46.47	54.30	48.20	46.27	51.63	46.27	44.70	51.13	46.13	45.13	45.63	41.93	42.37
23..........	61.57	54.00	49.53	61.27	52.93	48.83	58.43	49.63	46.40	57.37	49.83	47.60	51.47	45.00	44.00
24..........	62.57	55.97	51.50	62.13	54.83	50.73	59.87	51.83	48.00	58.37	52.03	49.30	54.37	47.37	45.23
25..........	58.43	56.50	53.23	57.90	55.63	52.70	57.60	54.07	49.87	57.40	54.20	51.53	55.87	50.13	47.17
26..........	49.97	51.03	50.77	49.57	50.50	50.33	50.63	51.67	49.73	50.90	51.60	50.70	51.97	49.93	48.17
28..........	46.43	45.70	46.43	46.77	45.63	46.43	45.97	46.83	47.37	45.87	46.57	47.10	45.27	48.20	48.47
29..........	50.73	46.73	46.33	51.13	46.80	46.60	47.70	46.37	46.50	46.97	46.27	46.57	46.73	47.60	47 90
30..........	56.67	50.30	48.13	56.23	49.90	48.07	52.53	47.97	46.73	51.30	47.63	47.07	49.23	47.60	47.53
Average...	**48.84**	**45.83**	**44.36**	**48.40**	**45.31**	**44.13**	**46.38**	**43.83**	**42.56**	**46.21**	**44.11**	**43.22**	**39.76**	**37.06**	**39.11**

TABLE 9.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, MAY, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	62.00	54.33	50.53	61.27	53.57	50.20	57.47	50.33	47.83	56.20	50.47	48.63	52.90	48.57	47.53
2..........	65.80	57.67	53.13	64.70	56.63	52.53	61.43	53.07	49.50	59.87	53.20	50.87	56.17	50.17	48.30
3..........	66.97	60.23	55.37	65.57	59.13	54.63	63.43	55.63	51.40	62.50	55.50	53.17	58.90	52.13	49.53
5..........	67.63	62.53	58.13	66.70	61.50	57.23	65.13	58.80	54.37	64.63	59.03	56.17	62.00	55.67	52.37
6..........	64.50	60.97	58.03	64.30	60.13	57.17	63.77	59.20	55.27	62.93	59.17	56.87	62.33	57.03	53.70
7..........	61.03	57.57	56.47	60.57	58.97	56.00	59.43	57.73	55.40	58.13	57.33	56.37	59.53	57.60	54.73
8..........	60.07	57.10	56.00	59.57	56.50	55.47	58.13	56.90	54.80	57.07	56.30	55.47	58.17	57.17	55.03
10..........	56.33	54.57	54.67	55.73	54.03	54.33	54.13	54.93	54.47	53.10	54.07	54.63	54.57	56.40	55.53
12..........	57.33	55.70	55.30	56.53	55.10	54.47	56.27	55.53	53.90	55.00	54.70	54.07	54.43	54.50	54.13
13..........	60.73	57.03	55.70	59.97	55.77	54.60	59.03	55.80	53.73	58.23	55.23	54.03	55.80	54.17	53.77
14..........	58.17	56.60	56.10	58.73	56.37	55.17	57.73	56.67	54.30	57.23	56.20	54.83	56.83	54.83	53.73
15..........	59.73	56.40	55.40	69.43	56.47	54.90	58.07	55.77	54.10	58.53	55.73	54.67	57.43	55.03	54.10
16..........	59.57	57.43	56.67	60.50	57.70	56.03	58.80	57.03	54.57	58.77	56.97	55.47	58.83	56.00	54.47
17..........	60.73	57.70	56.73	61.23	57.97	56.33	58.70	57.00	54.77	58.83	56.83	55.60	58.73	56.40	54.97
19..........	62.37	58.33	57.13	61.90	57.97	56.37	59.57	56.80	55.03	57.77	55.93	55.37	58.13	56.57	55.43
20..........	60.87	59.63	58.70	60.27	59.03	57.67	59.83	58.57	55.80	57.73	57.50	56.17	58.97	56.90	55.50
21..........	61.27	58.57	57.53	61.10	58.20	56.63	59.70	57.47	55.57	58.77	56.53	55.70	58.23	56.63	55.57
22..........	58.87	58.73	58.33	58.07	58.40	57.50	59.17	58.63	56.03	58.57	58.27	56.73	59.87	57.23	55.77
23..........	55.83	55.77	55.80	55.60	55.40	55.47	55.73	56.33	55.57	55.30	55.87	55.80	57.23	56.97	56.03
24..........	61.90	57.57	56.10	62.43	57.37	55.40	59.63	56.10	54.67	59.00	55.90	55.00	58.27	56.37	55.73
26..........	51.83	53.33	54.33	51.10	52.87	54.37	52.20	54.97	54.97	51.60	54.00	55.00	54.53	56.37	55.70
27..........	58.97	54.90	53.90	59.70	55.03	53.67	58.83	53.97	53.43	56.57	53.70	53.53	55.50	54.97	55.17
28..........	64.77	59.03	57.00	64.90	59.03	56.13	61.50	56.47	54.07	60.77	56.23	54.67	58.73	55.37	54.70
29..........	64.47	61.83	60.37	63.97	61.30	58.87	63.17	59.93	56.13	62.07	59.37	57.03	61.40	57.07	55.13
30..........	60.03	58.97	58.57	59.43	58.37	57.67	59.90	58.93	56.90	59.70	58.43	57.43	59.90	57.73	56.00
31..........	64.37	60.30	59.03	65.17	60.27	58.00	62.60	59.20	56.83	62.40	59.13	57.43	61.33	57.93	56.53
Average...	**61.01**	**57.80**	**56.35**	**60.75**	**57.43**	**55.65**	**59.36**	**56.61**	**54.36**	**58.51**	**56.22**	**55.03**	**58.03**	**55.61**	**54.20**

TABLE 7.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND. JUNE, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2..........	70.17	65.17	62.83	69.70	64.40	61.40	67.13	62.53	58.83	65.03	61.73	59.67	64.10	60.07	57.50
3..........	72.50	67.17	64.77	71.73	66.27	62.83	69.83	64.57	60.23	67.90	63.63	61.00	65.97	61.17	58.53
4..........	70.70	66.40	64.87	69.60	65.43	63.03	68.80	64.97	61.50	66.63	63.80	61.93	65.53	62.17	60.43
5..........	71.30	66.73	65.07	70.03	65.63	63.27	67.47	65.43	62.03	67.47	64.17	62.33	65.70	62.60	61.20
6..........	74.77	69.07	66.73	73.70	68.07	64.60	72.53	66.90	62.63	71.50	66.10	63.13	67.93	63.27	61.70
7..........	64.27	65.70	65.93	63.13	64.70	64.57	65.73	67.07	63.73	64.67	66.00	64.47	66.67	64.40	62.47
9..........	62.83	60.27	60.03	61.93	59.47	59.33	61.73	60.93	60.07	60.43	57.77	60.10	60.30	61.60	61.50
10..........	68.57	62.10	60.93	65.67	61.30	59.90	64.70	61.37	59.63	63.40	60.23	59.53	61.27	60.80	60.47
11..........	69.23	64.67	63.07	67.97	63.73	61.70	62.23	63.13	60.40	66.00	62.33	60.73	63.27	60.97	59.90
12..........	70.97	69.50	64.50	69.07	64.97	62.80	68.90	64.57	61.47	67.80	63.80	61.80	64.37	61.57	60.17
13..........	73.23	67.87	65.90	71.73	66.67	63.97	71.03	66.00	62.53	70.23	65.33	63.03	65.90	62.40	60.70
14..........	76.37	70.00	67.63	74.40	68.60	65.30	73.87	67.73	63.53	73.10	67.27	64.40	67.80	63.43	61.40
16..........	82.97	76.13	72.57	79.70	73.80	69.33	80.17	72.63	66.93	79.70	72.53	68.27	73.27	66.90	63.87
17..........	81.03	75.90	73.63	80.47	74.67	70.57	79.80	74.17	68.60	78.77	73.90	69.97	75.27	68.90	65.37
18..........	79.60	75.07	73.20	78.87	74.00	70.73	78.63	74.03	69.30	76.93	72.97	70.27	75.00	70.17	66.83
19..........	79.07	75.33	73.73	77.97	74.27	71.23	78.37	74.60	69.87	76.83	73.47	70.53	75.50	71.03	67.73
20..........	75.00	73.17	72.27	74.20	72.10	70.30	75.47	73.63	69.93	74.50	72.53	70.37	74.53	71.43	68.50
21..........	70.77	70.17	69.87	70.67	69.17	68.43	71.67	71.30	68.97	71.07	70.37	69.30	72.23	71.00	68.73
23..........	76.70	71.50	69.70	76.60	70.93	68.37	74.57	70.23	67.27	72.80	69.17	67.53	71.80	69.40	67.80
24..........	78.90	73.90	71.83	77.13	73.07	70.07	77.00	72.07	68.33	75.23	70.90	68.67	73.50	69.80	68.03
25..........	81.53	76.27	73.93	79.90	75.27	71.77	79.80	74.20	69.47	78.37	73.30	70.07	75.83	70.80	68.47
26..........	82.80	77.33	75.17	80.63	78.40	72.83	81.07	75.47	70.87	79.80	74.73	71.40	77.23	72.03	68.90
27..........	85.47	79.73	77.07	83.77	78.40	74.30	83.63	77.27	71.87	82.37	76.63	72.83	79.03	73.43	69.93
28..........	87.83	81.30	78.70	85.03	79.87	75.67	85.83	79.00	73.37	84.40	78.33	73.87	80.37	74.73	70.97
30..........	86.33	81.87	79.00	83.93	80.07	77.10	85.10	80.60	75.67	83.47	79.47	76.37	81.07	77.23	73.43
Average...	75.72	71.29	69.32	74.30	70.13	67.34	73.80	69.78	65.88	72.74	68.82	66.40	70.54	66.85	64.58

TABLE 8.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JULY, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	84.23	80.47	78.87	82.60	79.00	76.60	83.67	80.03	75.70	82.07	78.53	76.30	80.63	77.57	74.17
2..........	81.50	80.20	78.23	82.27	78.83	76.03	83.67	79.33	75.27	81.77	78.13	75.57	79.93	77.17	74.23
3..........	83.00	81.33	79.20	83.27	79.33	76.70	84.80	80.00	75.63	83.23	78.83	76.07	80.37	77.37	74.50
4..........	86.10	82.63	80.70	83.23	81.07	77.97	85.83	81.37	76.43	84.07	80.37	77.03	81.83	77.83	74.60
5..........	79.33	78.50	78.23	77.50	77.43	76.40	79.90	79.67	76.43	79.10	78.57	76.83	79.47	77.97	75.07
7..........	73.60	70.87	71.00	72.13	69.70	70.43	72.27	72.33	72.13	70.43	70.69	71.63	71.40	74.27	73.77
8..........	74.03	72.27	71.93	72.67	71.43	70.87	73.60	72.63	70.90	71.63	71.03	70.67	72.03	72.63	72.17
9..........	77.30	72.87	71.70	76.10	72.27	70.63	75.53	72.30	70.40	74.20	71.13	70.30	72.90	71.90	71.07
10..........	76.70	73.30	72.40	73.37	72.43	71.30	75.53	72.93	70.73	73.60	71.50	70.73	72.83	71.90	70.63
11..........	76.80	73.60	72.60	75.00	72.53	71.47	75.77	73.40	70.90	73.83	71.87	71.27	72.67	71.83	70.47
12..........	77.53	74.70	73.60	76.13	74.03	72.33	76.70	74.20	71.30	75.13	72.93	71.47	73.97	71.93	70.47
14..........	79.63	75.70	73.80	77.97	74.67	72.70	77.80	74.40	71.57	76.33	73.27	71.80	73.90	72.20	70.67
15..........	80.53	76.57	75.33	78.03	75.67	73.60	79.10	75.57	72.17	77.77	74.53	72.63	75.60	72.77	70.87
16..........	80.50	77.30	76.10	78.03	76.43	74.40	79.43	76.27	72.97	77.93	75.27	73.37	76.27	73.70	71.37
17..........	75.50	74.70	74.67	74.20	73.77	73.73	75.63	75.57	73.30	75.37	74.63	73.47	74.37	73.83	71.97
18..........	78.87	74.90	73.73	79.87	75.03	72.90	77.20	74.33	72.17	76.33	73.73	72.53	75.63	73.73	72.03
19..........	79.43	75.70	74.50	79.10	75.53	73.73	77.17	74.67	72.13	75.63	73.70	72.60	74.70	73.83	72.07
21..........	77.70	74.37	73.63	76.13	73.47	72.50	75.90	73.90	72.00	74.10	72.50	71.97	73.27	72.77	71.67
22..........	76.80	74.17	73.73	74.43	72.83	72.43	75.03	73.80	72.00	73.20	72.27	71.83	72.70	72.53	71.37
23..........	71.50	72.63	73.10	70.00	71.67	72.13	71.93	73.47	71.63	70.33	71.87	71.53	71.87	72.23	71.03
24..........	72.27	70.20	70.10	71.33	69.50	69.47	71.50	70.57	70.07	70.47	69.43	69.80	70.47	70.90	70.57
25..........	73.77	70.53	69.97	72.03	69.50	69.73	72.30	70.47	69.40	70.87	69.27	69.30	70.30	70.40	70.00
26..........	78.97	74.03	72.50	76.73	71.97	71.07	76.80	72.23	69.73	75.60	71.43	69.87	73.10	70.53	69.57
28..........	80.30	76.50	75.07	78.93	75.97	73.43	78.97	75.33	72.07	78.30	74.80	72.77	77.10	73.00	70.63
29..........	81.63	77.47	76.03	80.40	77.00	74.53	79.73	76.17	72.87	78.73	75.53	73.57	77.97	74.33	71.63
30..........	85.37	80.13	78.13	83.57	79.30	75.97	85.67	77.80	73.90	81.93	77.23	74.57	80.07	75.43	72.60
31..........	82.70	80.23	79.13	80.07	79.10	77.07	81.63	79.07	75.03	80.33	78.13	75.93	79.70	76.73	73.63
Average...	**78.73**	**75.77**	**74.74**	**77.23**	**74.79**	**73.34**	**77.89**	**75.25**	**72.55**	**76.38**	**74.11**	**72.79**	**75.34**	**73.75**	**71.96**

TABLE 9.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, AUGUST, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	79.17	76.83	76.40	78.03	76.00	74.90	78.63	77.03	74.90	77.40	76.03	75.10	77.90	76.40	74.07
2	80.60	76.50	75.60	77.87	75.80	74.37	79.23	76.50	74.17	77.73	75.13	74.23	77.57	76.10	74.17
4	77.20	74.27	73.93	76.17	73.57	72.93	76.27	74.73	73.33	76.47	73.30	73.17	75.23	75.03	73.83
5	75.97	73.70	73.47	74.40	72.80	72.50	75.00	74.13	72.67	73.33	72.57	72.57	73.73	74.40	73.30
6	75.97	74.30	73.97	74.57	73.40	72.90	75.23	74.37	72.40	73.73	72.93	72.33	73.90	73.77	72.63
7	77.60	73.63	73.10	76.60	73.23	72.13	76.10	73.50	71.87	75.07	72.43	71.83	73.97	73.20	72.27
8	79.00	75.90	74.90	78.43	75.43	73.73	77.87	75.10	72.37	77.00	74.23	72.70	76.17	73.83	72.13
9	77.33	75.30	74.93	76.87	75.20	74.40	76.77	75.37	73.17	76.43	74.57	73.33	75.70	74.77	72.93
11	69.73	69.27	70.17	70.73	69.57	70.57	69.47	71.23	71.70	69.00	70.13	71.20	71.50	74.43	74.30
12	72.63	70.33	70.07	73.10	71.00	70.40	71.40	70.37	69.97	70.53	69.50	69.83	71.57	72.77	72.87
13	78.07	73.23	71.97	78.07	73.37	71.40	75.40	71.53	69.80	74.57	71.03	70.03	72.97	72.07	71.53
14	80.80	76.40	74.80	80.60	76.10	73.60	78.63	74.13	71.00	77.73	73.73	71.63	75.77	72.53	71.10
15	82.80	78.07	76.47	82.00	77.57	74.87	80.67	76.03	72.50	79.93	75.73	73.43	78.23	73.93	71.67
16	84.07	80.43	78.50	82.43	79.80	76.53	83.07	78.47	74.17	82.03	77.83	74.90	81.03	75.57	72.70
18	78.97	76.30	75.60	79.43	76.10	74.57	78.67	76.43	74.43	78.33	75.70	74.53	78.07	76.90	75.27
19	77.60	75.27	74.80	78.47	75.67	74.43	77.03	75.70	73.83	75.93	74.83	74.13	77.27	76.60	75.03
20	76.83	74.47	74.17	77.40	74.40	73.83	75.37	74.60	73.23	74.20	73.43	73.23	75.33	75.60	74.50
21	75.67	74.90	74.60	74.80	74.67	73.93	75.53	74.83	73.10	74.77	73.90	73.20	76.07	75.03	73.80
22	74.37	73.63	73.60	74.43	73.67	73.03	74.60	74.07	72.40	74.13	73.47	72.73	75.37	74.50	73.37
23	72.23	70.90	71.07	72.53	71.27	71.33	71.47	71.70	71.40	70.83	70.90	71.43	71.93	73.43	73.00
25	70.17	69.47	70.03	69.47	69.10	69.90	69.23	70.13	69.90	68.30	69.13	69.90	68.67	70.90	71.00
26	76.33	71.83	70.77	76.00	71.83	70.20	73.90	70.40	69.17	73.03	69.90	69.30	71.40	70.03	70.07
27	75.90	72.43	71.63	75.10	71.90	70.90	74.17	71.30	69.67	73.10	70.63	70.10	71.70	70.43	69.67
28	71.20	71.07	71.33	70.00	70.53	70.70	70.67	71.30	70.00	69.80	70.37	70.20	71.07	70.67	69.70
29	69.87	68.67	69.03	69.00	68.23	68.90	68.97	69.27	69.07	68.27	68.33	69.03	69.00	69.93	69.63
30	70.97	69.17	69.03	70.07	68.87	68.73	69.83	68.93	68.37	69.07	68.20	68.43	69.20	69.33	69.27
Average	**76.19**	**73.70**	**73.23**	**75.64**	**73.43**	**72.53**	**75.12**	**73.50**	**71.87**	**74.26**	**72.61**	**72.02**	**74.24**	**73.54**	**72.45**

TABLE 10.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, SEPTEMBER, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	72.73	70.40	69.90	72.17	70.07	69.30	71.47	69.77	68.37	71.03	69.27	68.63	70.07	69.27	68.47
2........	77.57	72.60	71.10	76.83	72.10	70.10	75.00	70.63	68.67	74.57	70.27	69.13	72.13	69.70	68.90
3	79.10	75.40	74.00	77.90	74.87	72.47	77.63	73.80	70.07	76.80	73.03	71.00	75.30	71.17	69.10
4..........	75.20	73.83	73.57	74.20	73.30	72.43	74.37	73.53	71.03	73.50	72.83	71.77	74.47	72.27	70.20
5	75.70	72.27	71.60	75.03	71.63	70.77	73.93	71.83	70.53	73.37	71.00	70.77	73.00	71.83	70.60
6	75.83	73.20	72.40	74.93	72.37	71.20	74.70	72.47	70.40	73.80	71.40	70.77	73.43	71.77	70.43
8	73.10	72.90	72.90	72.43	72.23	71.87	73.40	73.30	71.37	72.87	72.27	71.80	74.13	72.70	71.07
9	69.40	68.40	69.20	68.57	67.80	68.90	68.70	69.83	70.13	67.87	68.47	70.00	69.43	71.60	70.97
10..........	68.20	67.03	67.60	67.40	66.47	67.67	67.17	68.10	68.60	66.17	66.63	68.27	67.70	70.00	70.10
11	69.70	67.43	67.50	68.93	67.00	67.37	68.00	67.53	67.53	67.13	66.17	67.37	67.60	68.87	69.20
12	70.00	68.53	68.47	69.13	68.23	68.30	69.03	68.37	67.40	68.13	67.33	67.53	69.03	68.53	68.13
13..........	65.57	66.03	66.80	64.93	65.73	66.90	65.43	66.87	67.03	64.30	65.70	66.90	66.53	67.97	68.00
15..........	63.87	63.40	64.13	62.90	63.07	64.47	62.97	64.20	64.97	62.07	62.93	64.63	63.20	65.67	66.47
16	63.53	64.20	64.90	63.17	64.07	64.97	63.57	64.70	64.57	63.23	63.83	64.57	64.23	65.20	65.43
17.	65.83	64.73	64.73	65.33	64.67	64.73	65.03	64.63	64.17	65.23	64.13	64.40	65.10	64.80	64.97
18..........	61.37	62.57	63.33	60.83	62.40	63.70	61.87	63.60	64.03	61.87	62.87	64.17	62.73	64.57	64.67
19..........	62.00	61.03	61.83	61.20	60.87	62.20	61.13	62.03	62.90	61.50	61.33	62.90	60.93	63.53	64.17
20..........	62.43	62.13	62.57	62.20	62.07	62.73	62.03	62.47	62.53	62.00	61.90	62.73	62.30	63.17	63.57
22.........	53.97	55.47	57.20	53.40	55.30	58.27	53.67	57.47	60.10	53.90	56.57	59.60	55.63	60.70	62.73
23........	54.43	54.50	55.53	54.37	54.43	56.80	53.37	55.60	58.13	53.33	54.87	57.63	53.80	58.67	61.47
24.........	69.93	58.00	57.63	62.13	58.67	58.40	58.63	56.90	57.60	58.97	56.73	57.60	56.77	57.73	59.90
25	64.30	61.43	60.83	64.63	61.69	61.00	61.77	59.60	58.90	62.00	59.60	59.47	59.40	58.53	59.53
26	60.93	62.13	62.47	60.07	61.97	62.40	60.77	61.57	60.47	60.60	61.23	61.30	60.80	59.73	59.83
27..........	58.40	57.77	58.70	58.47	57.50	59.27	56.90	58.37	59.93	56.77	57.60	59.83	56.70	59.37	60.30
29..........	62.23	61.03	60.80	62.13	61.07	69.80	61.17	60.07	59.43	61.13	59.63	59.63	60.07	59.03	59.83
30..........	64.90	62.77	62.10	65.03	62.80	61.77	63.63	61.47	60.20	63.67	60.93	60.63	62.43	59.87	59.97
Average...	**66.59**	**65.35**	**65.45**	**66.09**	**65.09**	**65.34**	**65.59**	**65.34**	**64.96**	**65.22**	**64.56**	**65.12**	**65.27**	**65.63**	**65.69**

TABLE 11.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, OCTOBER, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12	18″	6″	12″	18″	6″	12″	18″
1..........	64.07	62.97	62.87	63.53	62.90	62.53	63.87	62.07	61.73	63.80	61.50	61.87	63.03	61.23	60.77
2..........	58.07	60.47	61.60	57.10	60.00	61.73	58.93	61.67	61.60	58.93	60.77	61.93	60.73	61.67	61.47
3..........	59.33	58.60	59.07	59.07	58.40	59.40	58.53	59.23	60.13	58.70	58.50	60.10	59.00	60.50	61.37
4..........	59.13	58.30	58.73	59.03	58.00	58.97	57.93	58.60	59.40	57.87	57.67	59.33	57.70	59.90	60.93
6..........	63.90	61.30	60.87	64.13	61.27	60 73	61.90	60.33	59.57	62.03	59.40	60.00	60.63	59.73	60.13
7..........	69.83	63.77	62.87	66.57	63.60	62 43	64.43	62.10	60.57	64.50	61.33	61.33	63.17	60.73	60.40
8..........	66.13	64.93	64.40	65.73	64.73	63.83	65 43	63.73	61.87	65 57	63.37	62.60	64.93	62.00	61.20
9..........	65.63	64.17	63.93	65.30	63.87	63.40	64.93	63.70	62.40	64.93	63.20	63.03	64.47	62.73	61.93
10..........	66.63	64.93	64.40	67.13	64.90	63.90	66.00	64.27	62.70	65.97	63.57	63.30	65.43	63.27	62.53
11..........	62.90	64.23	64.57	61.93	64.07	64.43	63.17	64.73	63.57	63.17	63.27	63.83	64.87	64.07	63.07
13..........	52.17	53.60	55.47	51.43	53.27	56.67	52.23	55.87	58.93	52.03	54.03	58.27	53.67	59.90	62.00
14..........	53.87	53.50	54.43	54.47	53.73	55.80	52.67	54.53	56.63	52.83	52.70	56.10	53.10	57.37	59.10
15..........	55.80	55.23	56.07	56.10	55.57	56.63	54.63	55.13	56.10	54.63	53.60	56.03	54.27	56.40	58.10
16..........	54.73	55.60	56.43	54.63	55.83	57.13	54.10	55.80	56.37	54.33	54.37	56.43	54.90	56.37	56.93
17..........	55.67	55.50	56.07	55.47	55.63	56.67	55.00	55.53	56.13	55.33	54.00	56.23	54.97	55.97	57.93
18..........	51.70	54.13	55.47	50.63	54.00	56.27	52.20	55.37	56.37	52.33	54.10	56.50	54.13	56.20	57.43
20..........	45.83	48.20	50.10	45.37	48.17	51.40	45.80	49.97	53.00	46.03	48.47	52.50	48.03	52.97	55.80
21..........	46.37	47.77	49.23	46.17	47.87	50.53	45.50	48.80	51.53	45.67	47.33	51.17	47.13	51.57	54.70
22..........	42.90	45.93	47.97	42.10	45.87	49.47	42.73	47.47	50.53	43.27	46.17	50.13	45.53	50.43	53.47
23..........	40.20	43.43	45.73	39.53	43.13	47.30	40.23	44.97	48.67	40.83	43.73	48.27	42.53	48.73	52.37
24..........	45.00	44.87	45.33	44.77	44.63	46.27	43.50	45.07	47.10	44.07	42.57	46.87	42.10	46.43	50.30
25..........	43.50	44.97	46.17	42.73	44.87	47.23	43.00	45.33	47.40	43.40	44.37	47.33	42.87	45.97	49.17
27..........	44.43	46.00	47.00	44.10	46.17	48.00	44.23	46.20	47.53	44.60	44.83	47.57	44.23	45.57	48.47
28..........	44.40	45.33	46.30	43.87	45.43	47.47	43.60	45.47	47.20	44.20	43.33	47.43	43.80	45.97	48.37
29..........	44.37	45.37	46.37	43.83	45.43	47.33	43.80	45.63	47.20	44.37	43.83	47.27	43.70	45.83	48.20
30..........	41.00	43.63	45.27	39.67	43.37	46.50	40.70	44.53	46.83	41.47	43.53	46.83	42.30	45.63	48.07
31..........	40.00	42.10	43.77	39.90	41.87	44.93	39.73	43.17	45.77	40.07	41.80	45.73	40.47	44.70	47.70
Average...	**53.24**	**53.66**	**54.46**	**52.75**	**53.58**	**55.07**	**52.54**	**54.05**	**55.07**	**52.78**	**52.79**	**55.11**	**53.03**	**54.88**	**56.37**

TABLE 12.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, NOVEMBER, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	39.33	41.07	42.63	38.87	41.07	44.03	38.83	42.03	45.03	39.17	40.67	44.57	39.77	43.73	47.07
3..........	43.47	43.27	43.73	43.60	43.60	44.77	41.70	42.53	44.03	42.20	40.40	43.93	40.70	42.67	45.70
4..........	40.80	42.63	43.87	40.47	42.80	45.00	40.37	43.00	44.67	40.80	41.53	44.77	41.10	43.10	45.53
5..........	39.63	41.00	42.40	39.53	41.27	43.80	38.67	41.80	44.27	38.80	40.13	44.03	39.73	42.93	45.53
6..........	39.80	40.80	42.03	39.83	41.13	43.47	38.90	41.53	43.80	38.80	39.30	43.47	39.27	42.53	45.30
7..........	45.83	44.30	44.00	46.37	44.53	44.83	43.93	42.83	43.80	44.40	42.00	43.67	41.23	42.23	44.90
8..........	45.37	46.57	46.87	44.93	46.70	47.30	45.07	45.87	45.37	45.60	45.40	45.90	44.60	43.47	45.03
10..........	35.60	38.67	40.77	34.60	38.70	42.47	36.07	40.80	44.00	35.80	40.07	43.43	39.00	43.20	45.97
11..........	35.67	38.17	39.83	34.87	38.03	41.30	35.43	39.43	42.50	35.37	38.87	41.83	37.70	42.07	45.17
12..........	35.30	37.63	39.30	34.83	37.73	40.83	35.10	38.57	41.50	35.30	38.03	40.90	36.93	41.10	44.40
13..........	36.47	37.97	38.47	37.57	38.23	40.13	39.80	38.97	40.80	41.30	39.07	40.93	37.27	40.27	43.43
14..........	37.47	37.97	38.77	39.67	40.77	41.97	41.13	41.57	42.10	41.80	41.70	42.67	39.93	40.57	42.93
15..........	35.30	37.60	38.97	35.43	38.67	41.47	37.13	40.93	42.70	37.57	40.77	42.87	38.73	41.07	43.13
17..........	37.23	38.17	39.00	37.20	38.60	40.73	37.27	39.43	41.33	37.57	39.20	41.33	37.13	40.23	42.90
18..........	43.00	41.53	41.13	43.60	42.03	42.13	41.87	40.87	41.57	42.53	40.63	41.67	39.27	40.00	42.53
19..........	51.43	47.50	45.73	52.07	48.03	45.77	50.23	45.40	43.20	50.33	45.13	44.07	45.33	41.33	42.63
20..........	53.13	50.77	49.47	53.30	50.97	49.03	52.17	48.67	46.00	52.73	48.67	47.33	49.47	44.37	43.80
21..........	54.60	52.53	51.20	54.67	52.57	50.73	53.87	50.77	48.17	54.37	50.80	49.43	51.67	46.70	45.67
22..........	55.30	53.30	52.23	55.43	53.27	51.70	54.69	52.10	49.77	54.73	52.20	50.93	52.87	48.73	47.60
24..........	41.33	44.57	46.47	40.00	44.27	47.33	42.23	47.20	49.30	42.40	46.57	49.17	46.00	49.53	50.13
25..........	38.23	41.27	43.13	37.33	41.13	44.73	38.57	43.93	46.83	38.83	43.20	46.30	42.93	47.63	49.77
26..........	41.30	42.20	43.13	41.00	42.40	44.27	40.93	42.97	45.00	41.37	42.40	44.73	42.17	45.70	48.27
27..........	40.27	41.90	43.00	39.80	41.93	44.13	40.23	42.70	44.57	40.80	42.60	44.40	41.87	44.73	47.13
28..........	41.17	41.87	42.77	40.93	41.97	43.83	40.60	42.40	44.00	41.33	42.30	43.97	41.57	43.97	46.20
29..........	43.47	43.53	43.87	43.27	43.67	44.67	42.80	43.27	44.00	43.43	43.40	44.27	42.57	43.67	45.57
Average...	**42.02**	**42.67**	**43.71**	**41.97**	**42.96**	**44.42**	**41.90**	**43.18**	**44.33**	**42.29**	**42.60**	**44.42**	**41.95**	**43.42**	**45.45**

BEGINNING WITH THIRD YEAR.

TABLE 13.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. DECEMBER, 1913.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	50.60	49.33	48.53	50.50	49.47	48.40	49.73	47.73	46.23	50.27	48.07	47.00	47.73	45.20	45.77
2..........	50.80	49.80	49.30	50.77	49.57	49.23	50.23	48.80	47.50	50.73	49.10	48.27	49.03	46.63	46.57
3..........	47.33	48.63	49.00	46.73	48.47	49.17	47.80	48.93	48.37	48.17	48.97	48.93	48.57	47.70	47.67
4..........	43.87	44.67	45.90	42.47	44.43	46.63	43.13	46.47	47.57	43.63	46.47	47.63	45.20	47.47	48.33
5..........	41.80	43.57	44.70	41.30	43.50	45.60	41.83	44.60	46.37	42.03	44.27	46.27	43.67	46.47	48.20
6..........	40.87	42.37	43.70	40.17	42.27	44.73	40.53	43.47	45.40	40.83	43.07	45.13	42.07	45.47	47.53
8..........	34.67	38.37	40.67	34.63	38.97	42.57	36.10	40.93	43.90	36.03	40.43	43.40	39.93	43.93	46.80
9..........	33.20	36.70	38.83	33.00	37.20	41.00	34.57	39.17	42.33	34.20	38.53	41.57	37.53	42.43	45.40
10..........	33.53	36.30	38.00	33.40	36.80	40.10	34.20	38.17	41.17	34.17	37.37	40.37	36.50	41.13	44.40
11..........	33.33	36.13	37.67	33.10	36.60	39.70	33.90	37.57	40.50	34.07	37.07	39.80	36.17	40.13	43.20
12..........	33.23	35.97	37.23	33.00	36.10	39.10	33.53	36.97	39.77	33.63	36.50	39.10	35.50	39.23	42.27
13..........	34.93	36.27	37.30	34.90	36.80	39.03	33.53	36.77	39.30	34.03	36.43	38.80	34.87	38.60	41.63
15..........	33.87	36.27	37.63	33.30	36.47	39.17	34.13	37.10	39.23	34.67	37.00	38.99	34.33	37.87	40.70
16..........	36.60	37.03	37.67	36.40	37.27	39.00	35.17	36.93	38.93	35.83	36.87	38.73	33.87	37.57	40.37
17..........	35.50	37.13	38.07	35.00	37.40	39.40	35.17	37.40	39.13	36.30	37.53	39.10	34.30	37.43	40.13
18..........	34.30	36.43	37.67	33.67	36.53	38.90	34.43	37.27	39.17	35.00	37.33	39.03	34.57	37.30	39.93
19..........	33.23	35.57	36.90	32.47	35.63	38.40	33.67	36.77	38.77	34.10	36.70	38.63	34.10	37.20	39.90
20..........	33.10	35.13	36.53	32.50	35.40	38.03	33.40	36.37	38.50	33.73	36.17	38.20	34.37	37.07	39.73
22..........	30.97	33.07	35.53	28.73	34.07	37.13	32.47	35.67	37.90	32.40	35.23	37.47	33.87	36.80	39.40
23..........	31.93	33.77	35.17	31.13	33.80	36.70	32.20	35.07	37.40	32.27	34.77	36.93	33.43	36.43	38.97
24..........	32.23	33.70	35.00	32.03	33.83	36.47	32.13	34.90	37.03	32.43	34.50	36.53	32.97	36.03	38.47
26..........	32.77	34.20	35.30	32.33	34.60	36.80	32.43	34.87	36.73	32.80	34.73	36.60	32.97	35.77	38.27
27..........	32.27	34.03	35.03	31.43	34.10	36.50	32.23	34.73	36.60	32.63	34.53	36.33	33.03	35.40	38.00
29..........	32.27	33.73	34.73	31.97	33.97	36.37	32.07	34.23	36.10	32.37	34.13	35.83	32.10	34.80	37.27
30..........	32.17	33.77	34.57	31.93	33.90	36.27	31.93	34.03	36.00	32.33	34.03	35.77	32.40	34.43	36.97
31..........	32.33	33.77	34.77	32.20	34.10	36.13	32.00	34.10	36.03	32.57	34.27	35.90	31.33	34.70	37.00
Average...	**36.22**	**37.91**	**39.05**	**35.73**	**38.13**	**40.41**	**36.25**	**38.81**	**40.61**	**36.59**	**38.62**	**40.40**	**37.09**	**39.74**	**42.03**

TABLE 14.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. JANUARY, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	32.37	33.93	34.73	32.20	34.10	36.03	32.03	34.07	36.03	32.53	34.20	35.70	32.07	34.60	36.97
2..........	32.47	33.93	34.87	32.13	34.17	35.97	32.10	34.20	35.90	32.67	34.23	35.73	32.50	34.63	37.07
3..........	32.60	34.07	34.93	32.43	34.27	36.07	32.20	34.23	35.93	32.70	34.40	35.83	32.50	34.60	37.00
5..........	33.00	34.37	35.07	32.77	34.53	36.27	32.33	34.37	35.97	33.10	34.50	35.93	32.83	34.70	37.03
6..........	33.27	34.43	35.10	33.00	34.57	36.23	32.33	34.37	35.93	33.13	34.57	35.97	32.70	34.67	37.00
7..........	33.20	34.40	35.20	33.07	34.60	36.23	32.37	34.37	35.90	33.20	34.60	36.00	32.67	34.63	36.87
8..........	33.30	34.47	35.13	33.03	34.67	36.27	32.33	34.33	35.93	33.33	34.60	35.90	32.77	34.57	36.83
9..........	33.33	34.50	35.13	33.03	34.63	36.23	32.43	34.33	35.90	33.40	34.67	36.03	32.67	34.57	36.83
10..........	33.43	34.53	35.23	33.20	34.63	36.23	32.57	34.47	36.00	35.53	34.90	36.13	32.80	34.63	36.87
12..........	33.43	34.70	35.43	33.17	34.63	36.30	32.87	34.70	36.17	33.90	35.17	36.37	33.07	34.80	37.00
13..........	33.57	34.73	35.50	33.10	34.70	36.37	33.07	34.93	36.30	33.90	35.23	36.43	33.17	34.87	37.10
14..........	33.67	34.90	35.57	33.17	34.80	36.53	33.27	35.03	36.53	34.03	35.40	36.60	33.40	35.10	37.30
15..........	33.57	34.70	35.43	33.10	34.67	36.33	33.07	34.90	36.40	33.93	35.23	36.40	33.33	35.00	37.10
16..........	33.67	34.83	35.57	33.20	34.73	36.33	33.13	34.93	36.37	33.97	35.13	36.43	33.33	34.97	37.03
17..........	33.70	34.93	35.60	33.37	34.77	36.40	33.20	34.93	36.37	34.07	35.23	36.47	33.37	35.00	37.13
19..........	33.80	34.90	35.53	33.40	34.90	36.40	33.23	34.97	36.37	34.10	35.37	36.43	33.37	34.93	37.07
20..........	33.77	34.90	35.53	33.37	34.87	36.40	33.23	34.97	36.33	34.07	35.37	36.47	33.33	34.97	37.00
21..........	33.87	34.93	35.60	33.53	34.90	36.43	33.23	35.07	36.37	34.17	35.40	36.47	33.40	35.00	37.10
22..........	33.93	34.93	35.60	33.57	34.97	36.40	33.37	35.00	36.33	34.20	35.43	36.50	33.43	35.00	37.10
23..........	33.90	34.87	35.53	33.53	34.93	36.37	33.33	34.90	36.23	34.13	35.33	36.40	33.37	34.87	36.93
24..........	33.93	34.83	35.50	33.50	34.83	36.27	33.43	35.00	36.33	34.13	35.23	36.43	33.43	34.97	37.03
26..........	33.67	34.90	35.63	33.20	34.80	36.37	33.37	35.03	36.37	34.00	35.27	36.37	33.40	34.80	36.80
27..........	33.50	34.63	35.37	33.17	34.63	36.27	33.30	34.93	36.23	33.87	35.07	36.10	33.30	34.67	36.60
28..........	33.67	34.67	35.37	33.30	34.67	36.20	33.33	34.80	35.97	33.93	35.00	36.07	33.30	34.67	36.60
29..........	39.60	37.63	36.70	40.20	37.63	36.77	35.30	34.90	35.70	38.93	36.30	36.23	33.33	34.40	36.23
30..........	34.40	36.23	37.07	33.90	36.27	37.67	34.40	36.40	36.87	35.23	37.13	37.63	33.37	34.50	36.23
31..........	33.40	34.97	35.93	32.97	35.00	36.83	33.43	35.60	36.83	33.87	35.73	37.00	33.37	34.53	36.40
Average...	**33.70**	**34.81**	**35.48**	**33.39**	**34.85**	**36.38**	**33.05**	**34.80**	**36.21**	**34.00**	**35.14**	**36.30**	**33.10**	**34.76**	**36.90**

TABLE 15.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. FEBRUARY, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2..........	33.53	34.80	35.57	33.20	34.90	36.47	33.30	35.13	36.47	33.90	35.20	36.40	33.47	34.90	36.80
3..........	33.40	34.57	35.30	33.07	34.57	36.13	33.03	34.80	36.13	33.60	34.97	36.13	33.33	34.73	36.63
4..........	33.60	34.73	35.43	33.37	34.77	36.27	33.37	34.93	36.20	33.87	35.07	36.27	33.40	34.80	36.70
5..........	33.70	34.77	35.47	33.37	34.83	36.37	33.37	35.03	36.20	33.93	35.13	36.20	33.50	34.87	36.77
6..........	33.70	34.80	35.47	33.23	34.70	36.27	33.30	34.93	36.17	33.90	35.07	36.17	33.40	34.83	36.73
7..........	33.70	34.80	35.43	33.23	34.70	36.13	33.33	34.93	36.07	33.93	35.00	36.13	33.43	34.83	36.57
9..........	33.90	35.00	35.63	33.27	34.83	36.33	33.43	35.07	36.23	34.07	35.23	36.23	33.67	35.00	36.87
10..........	33.73	34.83	35.50	33.07	34.57	36.17	33.33	34.93	36.03	33.90	35.07	36.17	33.57	34.87	36.73
11..........	33.63	34.77	35.43	32.97	34.60	36.20	33.27	34.93	36.17	33.90	35.10	36.17	33.60	34.87	36.73
12..........	33.70	34.93	35.50	32.93	34.63	36.17	33.43	35.10	36.17	34.07	35.17	36.27	33.70	35.07	36.87
13..........	33.53	34.70	35.37	32.33	34.43	36.13	33.30	35.00	36.20	33.83	35.07	36.17	33.70	35.00	36.77
14..........	33.20	34.37	35.13	32.13	34.17	35.77	33.07	34.73	35.93	33.60	34.77	35.87	33.50	34.77	36.63
16..........	33.13	34.27	34.97	32.33	34.10	35.67	32.90	34.60	35.77	33.50	34.70	35.73	33.40	34.73	36.53
17..........	33.30	34.37	34.97	32.37	34.03	35.60	32.90	34.60	35.73	33.50	34.77	35.70	33.43	34.67	36.50
18..........	33.27	34.27	34.90	32.40	34.03	35.57	32.90	34.50	35.67	33.50	34.67	35.70	33.33	34.60	36.47
19..........	33.27	34.27	34.90	32.47	34.07	35.53	32.90	34.43	35.57	33.57	34.63	35.63	33.33	34.53	36.37
20..........	33.40	34.33	35.07	32.63	34.23	35.70	33.07	34.57	35.67	33.67	34.80	35.70	33.40	34.67	36.43
21..........	33.43	34.43	35.03	32.70	34.23	35.73	33.10	34.60	35.70	33.70	34.77	35.77	33.40	34.67	36.47
23..........	33.47	34.50	35.00	32.77	34.33	35.73	33.17	34.63	35.67	33.80	34.90	35.77	33.43	34.70	36.50
24..........	33.23	34.27	34.87	32.50	33.80	35.57	32.87	34.53	35.53	33.57	34.70	35.60	33.27	34.57	36.30
25..........	33.40	34.60	35.20	32.80	34.40	35.90	33.20	34.70	35.90	33.90	35.00	35.90	33.50	34.90	36.60
26..........	33.13	34.17	34.87	32.20	34.00	35.47	32.83	34.43	35.50	33.47	34.57	35.50	33.23	34.50	36.33
27..........	33.13	34.13	34.67	32.50	33.93	35.33	32.70	34.27	35.27	33.47	34.53	35.43	33.13	34.37	36.17
28..........	33.07	33.93	34.60	32.50	33.87	35.33	32.70	34.20	35.30	33.43	34.43	35.30	32.93	34.33	36.03
Average..	33.44	34.53	35.18	32.76	34.36	35.90	33.12	34.73	35.89	33.73	34.89	35.91	33.42	34.74	36.56

TABLE 16.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. MARCH, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2..........	33.50	34.30	34.80	32.97	34.17	35.40	33.17	34.53	35.53	33.83	34.80	35.70	33.30	34.57	36.33
3..........	33.27	34.20	34.77	32.77	34.13	35.47	33.13	34.50	35.43	33.70	34.73	35.57	33.20	34.43	36.13
4..........	33.30	34.23	34.67	32.73	34.10	35.33	33.07	34.43	35.40	33.73	34.67	35.50	33.33	34.40	36.10
5..........	33.30	34.23	34.70	32.80	34.17	35.40	32.97	34.37	35.33	33.70	34.67	35.43	33.17	34.37	36.00
6..........	33.37	34.20	34.67	32.77	33.87	34.90	32.97	34.40	35.33	33.73	34.63	35.37	33.13	34.30	36.03
7..........	33.40	34.23	34.73	32.93	33.93	35.00	33.10	34.43	35.37	33.67	34.67	35.50	33.17	34.33	36.00
9..........	33.37	34.27	34.80	33.07	34.20	35.37	33.03	34.43	35.30	33.77	34.67	35.47	33.17	34.27	35.90
10..........	33.47	34.33	34.83	33.17	34.17	35.27	33.07	34.40	35.33	33.73	34.70	35.43	33.17	34.23	35.97
11..........	33.40	34.23	34.77	33.17	34.10	35.27	33.07	34.37	35.23	33.80	34.63	35.37	33.13	34.23	35.97
12..........	33.47	34.37	34.80	33.20	34.23	35.33	33.10	34.43	35.33	33.73	34.70	35.47	33.17	34.30	35.93
13..........	33.43	34.13	34.53	33.03	34.07	35.20	32.97	34.27	35.10	33.60	34.50	35.20	33.17	34.17	35.70
14..........	35.27	34.90	34.80	34.17	34.33	35.10	32.87	34.10	34.77	33.47	34.07	35.00	33.00	33.83	35.33
16..........	40.83	39.00	38.07	41.63	38.93	37.53	38.07	36.23	35.70	39.63	36.97	36.80	33.07	33.83	35.10
17..........	36.03	37.07	37.47	35.70	37.03	37.83	35.80	37.27	37.00	36.77	36.90	37.83	33.07	34.00	35.53
18..........	34.60	35.97	36.63	34.27	36.03	37.17	34.60	36.37	37.00	35.23	35.80	37.27	33.23	34.40	36.03
19..........	34.17	35.27	36.00	33.37	35.10	36.77	34.07	35.77	36.63	34.67	36.00	36.83	33.33	34.53	36.33
20..........	34.00	34.93	35.60	32.60	34.53	36.10	33.80	35.40	36.30	34.27	35.50	36.37	33.27	34.60	36.47
21..........	33.70	34.77	35.37	32.23	34.23	35.77	33.57	35.07	36.07	33.97	34.60	36.10	33.33	34.63	36.43
23..........	33.50	34.43	35.00	32.70	34.17	35.50	33.33	34.70	35.57	33.73	34.07	35.63	33.13	34.43	36.20
24..........	35.53	35.07	35.13	35.27	34.97	35.53	34.50	34.63	35.47	34.97	34.37	35.50	33.20	34.43	36.10
25..........	39.00	36.80	36.07	38.90	36.33	35.80	36.87	35.23	35.13	37.50	35.10	35.40	32.47	33.47	35.07
26..........	42.17	39.43	38.27	42.17	38.97	37.50	39.87	37.33	36.27	40.60	37.57	36.87	32.53	33.50	35.10
27..........	41.33	41.90	41.30	40.90	41.50	40.23	41.73	40.93	38.37	42.43	41.17	39.47	32.67	33.83	35.37
28..........	41.63	39.87	39.37	41.70	39.63	39.10	40.37	39.23	38.60	40.93	39.30	39.17	32.87	34.03	35.73
30..........	42.80	43.00	42.43	42.43	42.60	41.67	43.20	42.43	40.43	43.63	42.57	41.33	39.03	36.73	37.40
31..........	43.77	41.67	41.10	44.40	41.63	40.87	42.20	41.07	40.40	42.53	41.07	40.87	39.90	38.20	38.53
Average...	**35.99**	**36.18**	**36.33**	**35.58**	**35.97**	**36.55**	**35.33**	**35.94**	**36.25**	**35.97**	**36.02**	**36.56**	**33.59**	**34.46**	**36.03**

TABLE 17.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. APRIL, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	44.37	43.27	42.50	44.37	43.10	42.00	43.70	42.47	40.87	44.13	42.37	41.50	42.50	39.73	39.60
2	40.27	41.40	41.70	39.87	41.20	41.70	40.83	41.93	41.10	41.10	41.83	41.70	41.43	40.83	40.37
3	39.90	39.80	40.07	40.03	39.77	40.47	39.40	40.27	40.53	39.83	40.13	40.70	39.87	40.57	40.83
4	36.20	38.00	39.03	36.33	38.17	39.83	36.30	39.20	40.00	36.53	38.90	40.13	36.73	40.27	40.90
6	34.67	36.67	37.67	34.27	36.87	38.53	34.93	37.53	38.47	35.03	37.30	38.37	36.80	38.63	39.90
7	35.27	36.03	36.67	35.10	36.20	37.67	34.40	36.37	37.63	35.23	36.27	37.57	35.57	37.80	39.33
8	34.07	35.90	36.73	33.73	35.90	37.47	33.73	36.10	37.30	34.37	36.27	37.40	34.93	37.10	38.80
9	33.83	35.07	35.97	33.80	35.33	36.93	33.17	35.47	36.87	33.53	35.47	36.90	34.43	36.50	38.33
10	35.67	35.47	35.93	36.57	35.87	36.70	33.90	35.10	36.37	34.30	34.97	36.30	34.00	35.93	37.87
11	39.40	38.17	37.80	40.67	38.73	37.90	37.27	36.47	36.57	38.00	36.80	36.70	34.43	35.63	37.33
13	42.80	40.17	39.43	43.90	40.67	39.63	40.47	38.73	38.00	40.50	38.97	38.57	37.53	36.63	37.43
14	47.43	43.30	41.83	48.20	43.40	41.20	45.07	41.00	39.23	44.60	41.17	39.83	40.30	37.50	37.87
15	50.27	46.70	44.97	50.47	46.37	43.63	48.63	44.53	41.17	47.97	44.47	42.10	43.83	39.37	38.73
16	50.60	47.47	45.93	50.67	47.07	44.67	49.40	45.77	42.83	48.77	45.70	43.70	45.60	41.20	40.10
17	54.13	49.43	47.37	54.53	48.97	45.83	52.03	47.27	43.97	51.23	46.80	44.80	47.77	42.87	41.40
18	59.47	53.43	50.47	59.77	52.83	48.30	56.93	50.17	45.57	56.03	50.00	46.70	51.73	44.80	42.77
20	44.87	47.27	48.17	43.83	46.43	47.60	46.60	49.40	48.00	46.53	48.57	48.67	48.70	48.27	46.30
21	47.50	45.73	45.57	48.13	45.57	45.43	46.57	46.13	46.03	46.27	45.57	46.13	46.90	47.00	46.57
22	53.20	49.90	48.33	53.67	49.80	47.47	51.60	48.17	45.87	51.20	47.90	46.40	49.83	46.83	46.30
23	52.33	50.30	49.17	52.37	49.87	48.27	51.27	49.27	46.97	50.43	48.80	47.47	50.07	47.47	46.40
24	51.87	50.30	49.50	51.73	49.90	48.50	51.13	49.60	47.37	50.43	49.03	47.83	50.20	47.73	46.77
25	55.83	52.20	50.57	56.83	52.27	49.33	54.37	50.43	47.73	54.27	50.27	48.27	52.40	48.10	47.00
27	59.33	54.90	52.87	60.97	55.43	51.87	57.03	52.70	49.37	56.90	52.47	50.40	55.07	50.53	48.67
28	62.37	58.10	55.63	63.90	58.60	54.20	60.87	55.77	51.23	60.63	55.53	52.30	59.00	52.43	49.80
29	58.50	57.63	56.43	58.80	57.73	55.17	59.17	56.97	52.67	59.00	56.90	53.87	59.93	54.40	51.47
30	52.57	52.53	52.67	53.57	52.67	52.47	53.03	53.70	52.30	52.33	53.03	52.87	54.93	54.50	52.60
Average	**46.80**	**45.35**	**44.73**	**47.16**	**45.34**	**44.34**	**45.84**	**44.64**	**43.23**	**45.74**	**44.44**	**43.74**	**44.79**	**43.18**	**42.82**

TABLE 18.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. MAY, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	51.10	50.73	50.93	51.17	50.73	51.17	51.00	51.73	51.03	50.53	50.80	51.17	52.13	53.10	52.37
2..........	53.60	50.67	50.47	54.07	50.83	50.23	52.43	50.83	49.97	52.53	50.03	50.23	52.43	51.80	51.53
4..........	58.70	55.50	54.00	59.17	55.47	52.97	57.67	54.23	51.17	58.00	53.83	52.37	57.23	53.07	51.33
5..........	58.60	56.57	55.23	59.57	56.30	54.03	58.33	55.67	52.30	58.60	54.97	53.57	58.27	54.07	52.10
6..........	57.10	55.60	54.67	57.47	55.33	53.77	57.07	55.23	52.70	57.37	54.37	53.80	57.33	54.63	52.83
7..........	53.57	53.43	53.43	53.57	53.30	53.07	53.70	54.10	52.57	54.30	53.30	53.50	55.30	54.63	53.30
8..........	52.70	52.50	52.43	52.47	52.23	52.17	52.87	53.00	51.80	53.30	52.17	52.70	54.13	53.93	53.20
9..........	55.33	52.47	51.73	56.30	52.43	51.40	53.83	52.03	51.00	54.50	51.70	51.73	53.93	53.20	52.77
11..........	53.20	55.50	55.80	55.37	55.10	55.17	53.40	56.40	53.63	54.73	56.43	55.03	57.43	55.30	53.17
12..........	46.63	48.63	50.10	45.80	48.13	50.57	47.00	50.57	51.87	46.83	49.70	51.70	48.37	53.03	54.03
13..........	48.93	48.37	48.70	49.17	48.23	49.07	48.17	48.77	49.57	48.37	48.33	49.40	47.97	50.50	52.23
14..........	50.50	49.37	49.30	51.27	49.57	49.43	49.40	49.10	48.93	49.90	49.00	49.30	49.30	49.87	50.90
15..........	52.03	50.37	49.97	53.30	50.53	50.07	50.87	49.70	49.13	51.63	49.93	49.73	50.60	49.87	50.30
16..........	55.57	52.23	51.27	57.00	52.43	51.07	53.67	51.00	49.60	54.67	51.53	50.60	52.37	50.43	50.17
18..........	60.90	56.77	55.07	58.27	56.63	53.90	59.33	54.93	51.87	59.70	55.47	53.23	57.20	52.67	51.20
19..........	63.70	59.30	57.27	64.47	59.03	55.70	62.33	57.40	53.40	62.57	57.73	54.93	60.23	54.43	52.30
20..........	65.93	61.50	59.33	66.20	61.23	57.60	64.70	59.73	55.10	64.73	59.87	56.83	63.30	56.63	53.63
21..........	67.13	62.87	60.93	66.97	62.33	58.93	66.03	61.50	56.80	65.93	61.43	58.40	65.17	58.77	55.43
22..........	67.47	64.10	62.20	67.83	63.63	60.37	66.80	62.87	58.10	67.07	62.93	59.80	66.73	60.70	57.07
23..........	64.20	61.67	60.77	64.33	61.20	59.43	63.77	61.77	58.53	64.00	61.60	60.00	64.53	61.63	58.50
25..........	66.77	61.37	59.47	68.10	61.53	58.33	64.97	59.97	57.40	65.07	60.03	58.33	63.97	60.50	58.93
26..........	72.10	66.43	63.73	73.27	65.97	62.03	70.63	63.97	58.77	70.77	64.33	60.73	69.40	62.07	59.20
27..........	71.07	67.90	65.97	71.07	67.73	64.37	70.77	67.07	61.90	70.87	66.97	63.37	70.93	64.43	60.43
28..........	68.57	66.67	65.10	69.53	66.30	63.73	68.60	66.13	62.27	68.67	66.10	63.60	69.43	65.43	62.13
29..........	71.07	66.53	64.73	71.57	66.83	63.60	70.33	65.53	62.00	70.60	65.77	63.40	69.77	65.43	62.77
30..........	70.10	67.27	65.83	70.33	66.93	64.37	70.03	66.90	62.93	70.27	66.67	64.43	70.70	66.60	63.43
Average...	59.87	57.47	56.48	60.29	57.31	55.64	59.14	56.93	54.40	59.44	56.73	55.46	59.16	56.41	54.82

TABLE 19.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. JUNE, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	72.13	68.10	66.27	72.63	67.63	64.93	71.37	67.03	63.23	71.43	67.17	64.80	70.93	66.73	64.13
2..........	70.20	67.07	65.97	69.97	66.57	64.70	72.67	66.87	63.73	69.03	66.63	65.07	69.80	67.03	64.50
3..........	68.53	66.93	66.07	68.17	66.43	64.87	68.50	66.93	63.73	68.10	66.43	65.00	69.60	67.07	64.63
4..........	65.83	65.60	65.20	65.20	65.17	64.23	66.70	66.37	63.70	66.57	65.93	64.77	68.33	66.73	64.77
5..........	62.83	62.23	62.33	63.10	62.03	62.03	63.13	63.43	62.50	63.13	62.97	63.20	64.97	65.60	64.67
6..........	64.93	62.00	61.57	65.93	62.40	61.50	63.73	62.23	61.23	64.20	62.20	61.93	64.47	64.30	63.80
8..........	78.60	71.97	69.03	79.30	72.23	67.00	76.70	68.80	63.47	76.60	69.23	65.37	75.27	66.50	63.50
9..........	80.73	74.93	72.10	80.87	74.37	69.60	79.33	72.17	65.97	78.93	72.20	68.13	78.90	69.70	65.13
10..........	81.90	76.50	73.93	81.47	75.00	70.97	80.93	74.23	67.97	80.47	73.77	70.07	81.03	72.27	67.20
11..........	77.60	74.77	73.47	76.63	72.77	70.90	77.33	74.30	69.33	76.80	73.00	71.00	79.03	74.00	69.03
12..........	75.83	73.00	72.00	74.80	71.70	69.93	75.50	72.97	68.93	75.10	71.53	70.33	77.70	73.80	69.93
13..........	75.50	72.70	71.50	74.27	70.93	69.57	75.17	72.50	69.03	74.67	71.00	69.93	77.23	73.63	70.10
15..........	74.10	71.50	70.50	72.93	70.77	68.97	73.80	71.37	68.13	73.47	70.13	69.27	75.80	72.70	69.93
16..........	70.43	68.70	68.53	68.90	67.83	67.50	70.00	69.50	67.50	69.63	68.00	68.50	72.77	71.83	69.67
17..........	72.23	69.07	68.37	70.50	68.13	67.10	71.13	68.90	66.67	70.70	67.47	67.53	72.73	70.80	68.97
18..........	73.77	70.50	69.37	72.00	69.50	67.77	72.60	69.63	66.70	72.10	68.37	67.73	73.93	70.80	68.57
19..........	68.40	69.37	69.37	67.40	68.63	68.30	69.37	70.10	67.27	68.90	68.87	68.43	72.67	71.17	68.67
20..........	65.40	64.27	64.73	64.43	63.57	64.43	64.83	65.73	65.57	64.80	64.40	66.00	67.17	69.07	68.23
22..........	68.87	66.10	65.30	68.70	65.83	64.90	68.10	65.70	64.10	68.27	64.97	64.90	67.90	66.90	66.43
23..........	76.30	70.50	68.37	76.77	69.57	67.20	73.80	68.30	64.77	74.10	68.33	66.10	72.43	67.17	66.13
24..........	76.90	72.47	70.47	78.23	72.93	69.43	75.73	70.53	66.33	75.97	71.07	68.03	74.77	69.43	66.83
25..........	78.27	74.23	72.17	79.27	74.43	70.63	77.83	72.47	67.83	77.80	72.60	69.67	76.67	71.07	68.00
26..........	70.87	73.50	72.70	71.27	73.03	71.27	74.83	73.43	69.27	74.57	73.33	70.83	75.93	72.77	69.27
27..........	65.87	69.13	69.23	67.60	68.47	68.43	70.00	70.47	68.80	69.93	70.00	69.70	71.10	72.07	70.10
29..........	61.50	63.37	64.20	61.40	63.27	64.50	63.57	65.37	65.50	63.60	64.73	65.87	65.77	68.70	68.80
30..........	66.60	64.97	64.23	68.80	65.47	64.37	67.17	64.70	63.97	67.40	64.50	64.53	67.50	67.03	67.13
Average...	**71.71**	**69.36**	**68.35**	**71.56**	**68.79**	**67.12**	**71.69**	**69.00**	**65.97**	**71.40**	**68.42**	**67.18**	**72.48**	**69.57**	**67.24**

TABLE 20.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, JULY, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	65.47	65.90	65.97	65.43	65.90	65.77	66.23	66.40	64.47	66.13	66.30	65.53	68.13	67.37	66.40
2..........	65.47	64.50	64.40	66.17	64.47	64.23	65.70	64.93	63.97	65.97	64.63	64.70	66.60	66.40	66.07
3..........	69.27	69.53	65.17	70.97	66.50	64.83	68.70	65.50	63.73	69.20	65.53	64.80	68.90	66.27	65.60
4..........	70.03	68.93	67.67	68.27	68.90	66.83	71.20	67.90	64.90	71.27	68.10	66.23	71.57	67.57	65.80
6..........	77.77	73.30	71.37	78.03	73.13	69.90	76.40	71.63	67.20	75.93	71.03	68.90	76.80	70.63	67.43
7..........	78.50	74.57	72.67	77.67	74.13	71.00	77.33	73.07	68.67	76.67	72.37	70.17	78.17	72.47	68.83
8..........	79.00	75.10	73.43	78.40	74.70	71.63	78.03	74.00	69.67	77.57	73.20	71.03	79.03	73.80	70.07
9..........	79.47	75.37	73.73	78.37	74.87	71.93	78.33	74.27	70.23	77.60	73.13	71.53	79.47	74.63	71.10
10..........	81.57	76.87	75.27	80.30	76.30	72.97	80.23	75.50	70.93	80.23	74.37	72.33	80.90	75.57	71.83
11..........	82.87	78.57	76.60	81.63	77.83	74.43	81.87	77.23	72.03	81.27	76.00	73.63	82.83	76.93	72.90
13..........	78.23	76.93	76.17	76.93	76.27	74.73	78.80	77.43	73.53	78.43	76.30	74.63	80.83	78.03	74.57
14..........	73.00	73.33	73.50	71.87	72.93	72.73	74.47	74.90	72.33	74.13	74.00	73.33	77.10	76.97	74.77
15..........	73.43	71.73	71.40	73.03	71.50	70.83	73.63	72.57	70.77	73.47	72.10	71.50	75.23	75.00	73.87
16..........	78.17	74.13	72.53	79.87	74.50	71.70	77.63	73.27	70.27	77.27	72.77	71.23	77.40	74.30	72.87
17..........	80.83	77.10	75.33	81.73	77.60	74.37	80.63	75.97	71.40	79.83	75.47	73.00	80.80	76.03	72.90
18..........	74.33	74.37	74.33	73.60	74.13	73.70	75.20	75.47	72.33	74.23	74.33	73.53	77.80	76.53	73.63
20..........	75.73	72.10	71.07	75.27	72.00	70.50	74.77	71.77	69.70	73.93	70.93	70.30	75.20	73.40	72.27
21..........	78.00	74.60	73.27	77.30	74.30	72.20	77.20	73.60	70.23	76.27	72.43	71.20	77.57	74.00	71.87
22..........	79.97	76.80	75.03	79.40	73.33	73.60	79.90	75.47	71.33	78.90	73.77	72.43	80.40	75.33	72.43
23..........	77.97	77.37	76.30	77.23	76.83	74.73	79.07	76.90	72.60	78.47	74.63	73.90	80.70	76.80	73.40
24..........	77.17	75.43	74.83	75.63	75.50	73.73	76.67	75.07	72.53	75.97	73.63	73.70	78.97	76.60	74.00
25..........	79.53	76.53	75.13	78.23	76.00	73.77	79.57	75.80	72.30	78.80	74.87	73.53	80.03	76.43	74.00
27..........	77.10	77.27	76.67	75.47	76.60	75.17	78.33	77.30	73.80	77.53	75.60	74.90	80.43	78.00	74.90
28..........	73.63	73.17	73.30	72.33	72.53	72.40	74.73	74.40	72.67	74.43	72.23	73.50	76.70	76.70	75.00
29..........	73.93	71.27	71.30	73.23	70.87	70.93	73.53	72.53	71.33	73.03	70.97	71.90	74.80	75.27	74.23
30..........	73.60	72.00	71.63	72.37	71.63	71.03	73.63	72.37	70.60	72.77	70.53	71.27	74.90	74.40	73.33
31..........	74.90	73.30	72.67	72.70	72.87	71.80	74.87	73.00	70.60	74.00	71.53	71.40	75.93	74.17	72.83
Average...	**75.92**	**74.08**	**72.62**	**75.24**	**73.30**	**71.53**	**75.80**	**73.27**	**70.15**	**75.31**	**72.27**	**71.26**	**76.93**	**74.06**	**71.74**

TABLE 21.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. AUGUST, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	77.17	74.70	73.67	75.83	74.10	72.33	76.93	73.73	70.87	76.23	71.83	71.73	77.30	74.30	72.57
3..........	76.87	74.97	73.97	73.93	74.23	72.73	77.07	74.40	71.63	76.23	73.00	72.57	77.77	75.13	73.27
4..........	75.97	74.03	73.50	73.93	73.13	72.30	75.43	73.93	71.70	74.60	72.03	72.57	78.33	75.30	73.47
5..........	77.00	74.27	73.60	74.77	73.40	72.47	76.00	74.00	71.57	75.00	71.90	72.40	76.43	75.20	73.40
6..........	73.93	75.03	74.33	75.27	74.20	73.00	76.60	74.50	71.70	75.87	72.63	72.67	76.70	75.33	73.50
7..........	78.57	76.33	75.03	77.63	75.40	73.50	78.97	75.33	72.00	78.07	73.43	73.17	79.07	75.50	73.60
8..........	80.80	77.27	76.10	79.00	76.23	74.43	79.73	76.33	72.90	78.77	74.23	74.03	79.87	76.47	74.00
10..........	77.47	76.60	76.27	76.03	75.83	74.90	77.83	76.90	74.00	77.33	75.53	75.00	78.73	77.40	75.13
11..........	75.53	72.50	73.00	74.63	71.97	72.37	73.53	74.27	72.90	73.13	72.83	73.63	75.63	76.00	75.10
12..........	72.03	70.63	70.77	71.50	70.43	70.73	72.33	72.03	71.33	71.70	70.80	71.87	73.37	74.70	74.23
13..........	70.90	71.07	71.27	70.30	70.80	71.07	72.00	72.33	70.67	71.43	71.33	71.40	73.40	73.87	73.27
14..........	68.80	68.73	69.30	68.07	68.53	69.23	69.27	70.10	69.60	68.87	69.50	70.13	70.63	72.33	72.33
15..........	69.23	67.77	67.97	69.67	68.17	68.33	69.27	68.83	68.50	69.13	68.33	68.97	69.27	70.90	71.33
17..........	71.40	70.23	69.87	71.77	70.30	69.60	71.47	70.10	68.33	71.53	69.93	69.27	71.53	70.20	69.90
18..........	74.90	72.27	71.30	75.60	72.47	70.70	74.50	71.33	68.87	74.60	71.40	70.03	74.10	70.93	69.97
19..........	76.40	73.67	72.87	75.47	73.57	71.93	75.60	73.07	69.93	75.77	72.97	71.27	75.57	72.20	70.57
20..........	75.60	73.77	73.17	75.23	73.63	72.27	75.53	73.37	70.60	75.63	73.33	71.87	75.60	73.03	71.33
21..........	75.40	73.47	72.93	75.77	73.50	72.23	75.33	73.47	70.90	75.63	73.23	72.10	75.50	73.43	71.87
22..........	75.13	73.23	73.80	75.73	73.17	72.17	75.37	73.53	71.17	74.97	73.03	72.20	74.97	73.77	72.23
24..........	71.57	72.37	72.83	70.77	72.00	72.27	72.43	73.43	71.37	71.73	72.67	72.40	74.00	74.23	72.73
25..........	68.30	67.97	68.87	67.67	67.17	68.87	68.17	69.63	69.80	67.47	68.60	70.13	69.23	72.30	72.30
26..........	69.27	68.37	68.73	68.43	68.13	68.63	68.90	69.17	68.60	68.13	68.13	68.93	69.90	71.03	71.13
27..........	72.10	69.93	69.57	71.13	69.83	69.20	71.47	69.60	68.10	70.30	68.80	68.70	71.70	70.53	70.33
28..........	68.83	69.27	69.57	67.93	68.80	69.30	68.90	69.80	68.47	68.23	68.90	69.17	70.77	70.77	70.13
29..........	65.93	66.47	67.20	65.30	66.10	67.30	66.23	67.60	67.50	66.10	66.83	67.83	67.67	69.77	69.83
31..........	69.03	66.93	66.50	68.53	68.83	66.43	68.20	66.53	65.67	68.30	66.13	66.20	67.50	67.33	68.07
Average...	**73.39**	**71.99**	**71.77**	**72.69**	**71.69**	**71.09**	**73.35**	**72.20**	**70.37**	**72.88**	**71.20**	**71.16**	**74.02**	**73.15**	**72.14**

TABLE 22.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. SEPTEMBER, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	71.40	69.53	68.83	70.77	69.63	68.47	71.00	68.83	66.83	71.07	68.53	67.63	70.13	68.07	67.67
2..........	69.27	69.20	69.20	68.50	68.93	68.90	69.73	69.27	67.37	69.67	69.00	68.43	69.97	68.90	68.20
3..........	65.33	65.67	66.43	64.57	65.77	66.77	65.97	67.00	66.77	65.83	66.53	67.47	66.87	68.53	68.53
4..........	63.63	64.30	65.13	62.80	64.23	65.60	64.23	65.70	65.83	63.90	65.10	66.33	65.43	67.47	68.07
5..........	64.30	64.00	64.47	63.90	63.83	64.83	64.10	64.77	64.87	63.80	64.17	65.17	64.37	66.40	67.17
7..........	61.60	63.33	64.37	61.00	63.17	64.77	62.87	64.80	64.60	62.93	64.23	65.23	64.37	65.93	66.27
8..........	60.57	61.20	62.30	60.23	61.10	62.97	61.23	62.90	63.57	61.20	62.40	63.90	62.30	64.83	65.80
9..........	61.00	60.97	61.73	60.53	60.60	62.17	61.10	62.17	62 60	60.83	61.53	63.03	61.30	63.70	64 90
10..........	59.30	60.50	61.63	57.93	60.13	62.13	59.63	61.87	62.23	59.40	61.17	62.53	60.63	63.13	64.23
11..........	58.23	59.67	60.80	57.60	59.43	61.40	58.77	60.97	61.47	58.67	60.33	61.80	59.67	62.23	63.50
12..........	57.33	57.73	58.80	56.77	57.40	59.53	57.10	58.97	60.33	57.30	58.43	60.53	57.53	61.00	62.70
14..........	62.07	60.93	60.90	62.53	61.13	61.23	61.53	60.57	59.90	61.77	60.47	60.80	61.10	60.60	61.57
15..........	65.87	63.87	63.20	66.00	64.07	63.03	64.83	62.63	61.07	65.03	62.67	62.10	63.83	61.60	61.70
16..........	68.33	65 60	64.67	68.37	65.67	64.23	67.30	64.23	62.13	67.23	64.23	63.27	66.00	62.90	62.37
17..........	67.10	65.60	65.23	66.60	65.43	64.83	66.40	65.03	63.23	65.87	64.67	64.30	66.10	64.17	63.30
18..........	67.50	65.87	65.50	66.83	65.63	65.10	66.70	65.47	63.77	66.10	64.87	64.57	66.43	64.97	64.13
19..........	67.97	66.30	65.97	67.60	66.13	65.47	67.23	65.93	64.20	66.53	65.30	64.87	67.23	65.63	64.73
21..........	73.60	70.17	68.33	73.53	69.83	67.67	72.43	68.43	65.67	71.80	68.00	66.47	71.80	67.37	66.03
22..........	72.40	70.80	69.97	72.10	70.53	68.93	72.13	69.93	66.77	71.70	69 53	67.93	72.53	68.93	66.83
23..........	64.20	66.33	67.30	63.37	65.90	67.13	65.50	67.90	66.87	65.33	67.27	67.57	68.23	69.17	67.90
24..........	58.83	60.80	62.47	57.00	60.30	63.10	59.63	63.47	64.73	59.60	62.60	64.97	62.47	67.07	67.50
25..........	58.70	59.37	60.60	57.30	59 17	61.30	58.97	61.27	62.50	58.97	60.47	62.37	60.70	64.67	66.10
26..........	58.33	58.93	59.90	58.03	58.77	60.67	58.33	60.30	61.23	58.23	59.60	60.90	60.00	63.07	64.53
28..........	60.30	59.87	60.47	59.57	59.77	60.93	59.60	60.30	60.40	59.30	59.73	60.53	60.40	61.80	62.63
29..........	62.10	60.83	60.97	61.23	60.77	61.27	61.00	60.63	60.40	60.83	60.30	60.93	61.40	61.60	62.30
30..........	62.20	61.57	61.77	61.23	61.37	61.90	61.13	61.50	60.77	61.13	61.10	61.07	62.23	62.00	62.20
Average...	**63.91**	**63.58**	**63.89**	**63.30**	**63.42**	**64.01**	**63.79**	**64.05**	**63.47**	**63.62**	**63.55**	**64.04**	**64.35**	**64.84**	**65.03**

TABLE 23.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. OCTOBER, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1..........	60.87	60.46	61.00	60.10	60.10	61.27	59.57	60.67	60.77	59.57	60.10	61.20	60.87	61.87	62.30
2..........	60.27	60.03	60.60	59.73	59.57	60.83	58.93	60.10	60.33	58.90	59.47	60.80	60.33	61.60	62.17
3..........	59.80	59.73	60.30	59.30	59.40	60.53	58.77	59.83	59.93	58.77	59.20	60.40	59.97	61.33	61.97
5..........	64.93	62.77	62.13	64.60	62.57	61.83	63.53	61.50	59.90	63.70	60.87	60.90	63.43	61.30	61.47
6	66.57	64.37	63.60	66.20	64.03	63.10	65.97	63.03	61.27	65.40	62.90	62.20	65.17	62.37	61.87
7..........	66.27	64.47	64.03	65.97	64.10	63.53	65.13	63.67	62.00	65.20	63.43	62.93	65.37	63.23	62.57
8..........	65.77	65.10	64.87	64.93	64.80	64.20	65.50	64.53	62.63	65.43	64.43	63.70	66.20	64.10	63.13
9..........	66.97	64.90	64.43	65.83	64.67	63.97	65.97	64.47	62.83	66.17	64.27	63.60	66.03	64.30	63.63
10..........	65.10	64.97	64.97	64.60	64.73	64.47	65.33	65.00	63.23	65.33	64.93	64.30	66.23	64.90	64.07
12..........	55.93	58.03	59.63	54.20	57.37	66.20	56.77	60.30	61.37	56.83	59.83	61.60	59.23	63.00	63.87
13..........	53.43	56.23	57.90	51.57	55.93	58.63	54.60	58.70	59.57	54.77	57.93	59.97	55.17	61.40	62.87
14..........	51.17	53.33	55.03	49.80	53.13	56.33	51.73	55.33	67.60	51.93	55.07	57.87	54.50	59.30	61.50
15..........	55.53	54.87	55.33	54.83	54.97	56.17	54.83	55.13	56.20	55.13	55.00	56.47	55.13	57.57	59.90
16..........	57.27	57.63	57.20	56.23	57.20	57.60	57.13	56.67	56.37	57.33	56.80	57.03	57.03	57.37	58.80
17..........	56.13	56.57	57.17	55.40	56.43	57.53	55.97	56.83	56.87	56.27	56.73	57.43	56.47	57.27	58.20
19..........	54.83	55.33	56.13	54.70	55.13	56.80	54.57	55.97	56.57	54.73	55.73	56.97	54.67	56.73	58.10
20..........	56.10	55.67	56.17	56.03	55.87	56.70	55.57	55.93	56.20	55.83	55.37	56.47	55.37	56.63	57.73
21..........	57.33	56.80	57.07	57.27	57.13	57.60	56.93	56.77	56.37	57.23	56.77	57.13	56.53	56.63	57.53
22..........	57.53	57.10	57.43	57.13	57.33	57.77	57.03	57.23	56.83	57.30	57.23	57.63	56.77	57.00	57.70
23..........	55.97	56.30	57.13	55.73	56.40	57.50	55.77	56.90	56.83	56.03	56.87	57.57	56.17	57.10	57.77
24..........	53.00	54.93	56.50	52.40	55.37	57.20	53.77	56.17	56.77	54.10	56.33	57.43	55.30	57.03	57.80
26..........	48.23	49.47	51.27	48.23	48.77	52.80	48.27	51.37	53.47	49.00	51.10	53.50	49.83	53.87	56.47
27..........	41.27	43.00	48.07	44.67	46.77	49.20	41.80	48.47	51.67	52.57	48.03	50.87	46.40	52.17	55.20
28..........	43.10	45.40	47.20	42.17	45.03	48.37	42.37	46.83	49.60	42.97	45.63	49.10	43.97	49.90	53.57
29	45.13	46.90	48.23	43.70	47.47	48.03	45.60	47.30	48.77	46.13	47.43	48.70	45.70	48.80	52.10
30..........	44.23	45.87	47.40	44.13	45.53	48.10	43.67	46.03	49.03	44.10	46.27	48.60	44.37	48.13	51.10
31..........	45.57	46.13	47.40	45.60	46.33	48.03	45.37	46.43	48.13	45.67	46.40	48.30	44.70	47.60	50.33
Average...	55.86	56.16	56.97	55.54	56.15	57.57	55.56	56.71	57.45	55.79	56.45	57.51	56.33	57.87	59.03

TABLE 24.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND. NOVEMBER, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2..........	48.27	49.30	50.00	47.53	49.47	50.83	48.07	49.33	49.73	48.40	49.20	50.43	47.93	48.77	50.30
3..........	49.70	49.30	49.73	48.80	49.60	50.37	48.83	49.20	49.77	49.30	49.23	50.07	48.17	49.00	50.63
4..........	47.60	49.10	49.97	46.67	49.40	50.83	48.17	49.70	50.13	48.47	49.60	50.70	48.40	49.57	50.83
5..........	44.20	46.60	48.13	41.50	46.50	49.40	45.10	48.33	49.63	45.30	48.07	50.03	46.50	49.43	51.10
6..........	42.77	44.90	46.30	42.03	45.10	47.67	43.80	46.47	47.30	43.87	46.27	48.67	44.60	48.37	50.80
7..........	46.33	45.97	46.50	45.33	46.10	47.50	45.80	46.17	47.67	46.17	46.23	47.90	44.90	47.53	50.00
9..........	39.17	41.67	43.73	37.00	42.20	45.40	40.03	44.03	46.77	39.87	44.00	46.70	42.10	46.70	49.17
10..........	41.00	42.23	43.43	39.10	42.23	44.87	40.43	43.10	45.33	41.17	43.00	45.47	40.93	45.27	48.30
11..........	40.27	41.93	43.23	39.90	42.20	44.73	40.37	42.83	44.90	41.23	42.93	45.20	40.83	44.73	47.43
12..........	39.33	41.17	42.63	36.33	41.17	44.17	39.60	42.47	44.63	40.00	42.33	40.77	40.30	43.97	46.83
13..........	42.13	42.90	43.50	38.30	43.27	44.73	41.80	42.87	44.20	42.40	42.97	44.53	41.30	43.50	46.30
14..........	39.57	41.30	42.67	38.03	41.33	44.03	39.90	42.27	44.27	40.30	42.23	44.43	40.17	43.37	45.93
16..........	38.07	41.60	43.53	37.43	41.57	44.83	39.17	43.23	44.70	39.50	43.10	45.20	40.50	43.80	45.77
17..........	35.83	38.93	40.80	35.13	39.00	42.50	36.53	40.97	43.77	36.70	40.67	43.37	38.90	43.13	45.70
18..........	33.63	37.00	38.93	33.23	47.17	40.87	34.60	39.27	42.37	34.67	38.60	41.87	37.07	41.93	45.20
19..........	33.80	36.47	38.10	33.43	36.73	39.93	34.37	38.10	41.13	34.57	37.73	40.73	36.20	40.83	44.33
20..........	33.83	36.33	37.80	33.23	36.40	39.53	34.07	37.63	40.47	34.50	37.30	40.13	35.67	39.97	43.40
21..........	33.70	36.17	37.53	33.10	36.13	39.20	33.93	37.27	39.80	34.40	37.03	39.63	35.17	39.40	42.57
23..........	32.57	35.33	36.93	31.83	35.40	38.53	33.60	36.80	39.27	34.00	36.63	39.10	34.60	38.27	41.47
24..........	32.13	34.70	36.37	31.63	34.80	37.93	33.37	36.43	38.67	33.60	36.27	38.60	34.33	37.83	40.93
25..........	32.57	34.83	36.23	32.27	34.90	37.80	33.33	36.17	38.27	33.87	36.13	38.27	34.23	37.53	40.63
26..........	37.67	36.70	36.97	37.13	36.67	38.10	35.67	36.30	38.07	37.23	36.70	38.23	34.10	37.30	40.30
27..........	38.10	39.70	40.17	37.67	39.87	40.83	38.40	39.07	39.33	39.33	39.87	40.23	34.67	37.30	40.13
28..........	34.87	37.47	38.73	34.30	37.43	39.93	35.30	38.43	40.07	35.72	38.53	40.57	35.13	37.50	40.33
30..........	44.50	42.53	41.63	44.67	42.90	41.93	43.03	40.37	39.93	43.77	40.83	40.50	39.30	37.97	40.37
Average...	**39.26**	**40.97**	**42.14**	**38.22**	**41.50**	**43.46**	**39.49**	**41.87**	**43.61**	**39.93**	**41.72**	**43.65**	**39.84**	**42.92**	**45.55**

BEGINNING WITH FOURTH YEAR.

TABLE 25.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, DECEMBER, 1914.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
2..........	46.00	42.97	46.50	45.47	49.43	46.57	45.90	46.17	45.30	46.27	46.17	46.17	45.73	45.40	45.40
3..........	38.73	39.80	40.87	37.57	38.63	40.27	38.57	40.57	41.13	39.23	40.67	41.73	40.17	41.67	43.37
4..........	35.57	36.57	37.63	35.57	36.40	37.43	39.03	37.23	37.83	36.13	37.20	38.33	37.03	38.57	40.70
5..........	36.57	37.03	37.43	36.63	37.00	37.57	36.20	37.00	37.17	37.03	37.00	37.60	36.80	37.63	39.30
7..........	33.77	34.53	35.37	33 47	34.30	35.33	33.67	34.97	35.47	34.13	34.93	35.87	34.90	36.07	37.70
8..........	32.47	33.57	34.33	32.47	33.47	34.37	32.53	33.87	34.27	32.97	33.70	34.60	33.60	34.77	36.73
9..........	32.37	33.30	34.07	32.07	33.33	34.17	32.40	33.63	34.03	32.67	33.40	34.27	33.40	34.30	36.07
10..........	32.00	33.10	33.87	31.80	32.90	33.77	32.40	33.50	33.80	32.30	33.07	33.83	33.10	33.90	35.53
11..........	30.63	32.40	33.27	28.50	31.10	32.77	32.10	33.20	33.53	31.17	32.23	33.30	32.27	33.57	35.20
12..........	30.17	31.60	32.53	28.57	30 27	31.97	31.53	32.83	33.13	30.07	31.53	32.47	32.30	33.30	34.77
14..........	30.17	31.87	32.70	25.23	28.33	31.13	31.37	32.73	33.13	30.70	31.90	32.70	32.27	33.00	34.43
15..........	28.73	30.17	31.30	23.23	26.03	28.30	30.20	32.13	32.57	28.33	30.03	31.67	31.33	32.67	34.13
16..........	28.60	30.07	31.00	22.10	25.33	27.60	29.90	31.77	32.43	28.17	29.70	31.13	31.23	32.43	33.97
17..........	28.37	29.87	30.73	22.80	25.23	27.10	29.60	31.43	32.57	28.13	29.50	30.83	31.00	32.33	33.70
18..........	28.93	29.87	30.50	24.93	26.17	27.37	29.63	31.10	31.83	28.63	29.33	30.47	30.97	32.10	33.47
19..........	31.10	31.57	31.77	29.87	30.93	31.27	30.83	31.57	31.70	30.60	30.83	31.23	31.87	32.00	33.37
21..........	31.17	31.70	31.97	29.37	30.70	31.23	30.93	31.77	31.70	31.00	31.20	31.63	31.70	32.00	32.27
22..........	31.17	31.80	32.07	29.00	30.00	30.83	30.70	31.70	31.90	31.00	31.27	31.90	31.63	32.10	33.27
23..........	31.23	31.83	32.17	29.17	30.23	31.07	30.67	31.60	31.90	30.93	31.37	31.83	31.53	32.03	33.17
24..........	31.33	31.97	32.23	28.90	30.53	31.27	30.47	31.63	31.80	31.37	31.37	31.90	31.56	32.03	33.20
26..........	30.50	31.30	31.90	26.77	28.60	29.90	30.33	31.37	31.63	30.27	30.97	31.67	30.87	31.83	33.10
28..........	31.43	31.97	32.10	29.40	30.93	31.43	30.73	31.50	31.53	31.10	31.30	31.67	31.50	31.63	32.67
29..........	31.80	32.20	32.27	30.67	31.70	32.00	31.07	31.67	31.63	31.47	31.50	31.87	31.90	31.73	32.60
30..........	32.10	32.37	32.33	31.53	32.13	32.33	31.33	31.97	31.80	31.80	31.83	32.07	32.03	31.87	32.70
31..........	31.93	32.40	32.43	30.63	31.60	32.17	31.27	32.10	31.93	31.60	31.93	32.20	31.77	31.97	32.80
Average...	**32.28**	**33.03**	**33.73**	**30.23**	**31.81**	**32.77**	**32.54**	**33.56**	**33.83**	**32.29**	**32.96**	**33.72**	**33.30**	**34.04**	**35.35**

TABLE 26.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JANUARY, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
2..........	32.13	32.40	32.43	31.43	32.10	32.33	31.37	32.03	31.90	31.93	31.93	32.20	31.90	31.80	32.70
4..........	31.73	32.30	32.40	30.87	31.53	32.13	30.97	31.73	31.73	31.40	31.57	32.10	31.30	31.53	32.50
5..........	32.00	32.30	32.33	31.43	32.00	32.27	31.13	31.73	31.60	31.67	31.33	32.10	31.57	31.53	32.37
6..........	32.13	32.30	32.37	31.83	32.13	32.30	31.33	31.93	31.63	32.07	31.67	32.17	32.00	31.63	32.37
7..........	32.27	32.47	32.43	32.10	32.33	32.40	31.80	32.10	31.83	32.43	32.30	32.30	32.33	31.93	32.37
8..........	32.33	32.53	32.63	32.13	32.37	32.43	31.93	32.20	31.97	32.50	32.37	32.30	32.30	32.03	32.47
9..........	32.33	32.60	32.87	31.83	32.37	32.57	31.87	32.27	32.03	32.53	32.40	32.33	32.43	32.03	32.57
11..........	32.20	32.57	32.80	31.87	32.27	32.60	31.50	32.17	32.00	32.17	32.27	32.30	32.30	31.93	32.43
12..........	32.30	32.77	33.03	31.93	32.40	32.67	31.73	32.23	32.03	32.37	32.30	32.43	32.30	31.97	32.57
13..........	32.30	32.80	33.07	31.97	32.33	32.77	31.73	32.20	32.07	32.30	32.30	32.47	32.30	32.03	32.53
14..........	32.30	32.73	33.07	31.73	32.33	32.83	31.47	32.20	32.07	32.20	32.30	32.53	32.30	31.87	32.53
15..........	32.30	32.80	33.17	31.50	32.37	32.83	31.57	32.17	32.07	32.27	32.27	32.60	32.30	31.97	32.53
16..........	32.33	32.87	33.17	31.00	32.37	32.93	31.47	32.17	32.07	32.20	32.30	32.60	32.30	31.97	32.57
18..........	32.37	32.87	33.13	32.13	32.53	32.83	31.93	32.30	32.13	32.47	32.40	32.67	32.30	32.03	32.47
19..........	32.40	32.87	33.17	32.10	32.53	33.00	31.90	32.23	32.13	32.30	32.40	32.77	32.30	31.97	32.47
20..........	32.30	32.85	33.15	32.10	32.50	32.95	31.75	32.35	32.25	32.20	32.40	32.85	32.35	32.00	32.50
21..........	32.30	32.77	33.17	31.53	32.27	32.87	31.57	32.30	32.27	32.17	32.30	32.90	32.37	32.07	32.63
22..........	32.17	32.83	33.20	30.33	31.37	32.67	31.40	32.37	32.37	31.87	32.37	32.93	32.43	32.17	32.80
23..........	32.07	32.57	33.00	30.27	30.90	32.30	31.33	32.27	32.30	32.03	32.27	32.67	32.33	32.10	32.73
25..........	31.27	31.97	32.47	29.17	29.93	31.07	30.97	32.07	32.17	31.47	31.97	32.50	32.00	32.07	32.70
26..........	30.97	31.83	32.37	28.53	29.83	30.80	30.73	31.97	32.13	31.30	31.77	32.43	31.87	32.07	32.73
27..........	30.70	31.40	32.13	27.70	28.63	30.07	30.57	31.87	32.10	31.13	31.63	32.40	31.70	31.97	32.77
28..........	30.47	31.13	32.03	27.43	28.50	29.97	30.43	31.70	31.97	30.93	31.57	32.43	31.63	32.00	32.90
29..........	30.37	30.97	31.67	27.23	28.27	29.60	30.33	31.47	31.90	30.73	31.33	32.30	31.47	31.87	32.77
30..........	29.07	29.90	30.87	24.63	25.83	27.77	29.53	31.03	31.67	30.17	30.83	32.17	30.80	31.57	32.47
Average...	31.81	32.30	32.65	30.59	31.28	31.96	31.28	32.05	32.02	31.87	32.03	32.46	32.05	31.93	32.58

TABLE 27.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, FEBRUARY, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	″4	6″	2″	4″	6″
1..........	32.10	32.17	32.20	32.13	32.33	32.43	31.27	31.63	31.50	32.03	31.77	32.10	32.17	31.70	32.43
2..........	32.30	32.40	32.40	32.23	32.40	32.57	31.57	32.03	31.63	31.80	32.00	32.30	32.30	31.93	32.47
3..........	32.03	32.40	32.40	32.23	32.47	32.50	31.30	32.03	31.70	31.07	31.40	32.30	32.33	31.93	32.47
4..........	31.07	31.73	32.17	32.20	32.43	32.50	31.03	31.80	31.70	30.80	31.20	32.00	32.30	31.87	32.43
5..........	32.00	32.30	32.33	32.10	32.37	32.40	31.27	31.83	31.53	31.73	31.63	32.03	32.20	31.87	32.37
6..........	32.23	32.37	32.40	32.17	32.40	32.47	31.63	32.07	31.67	32.30	32.13	32.27	32.30	31.90	32.50
8..........	32.27	32.43	32.50	32.23	32.47	32.67	31.53	32.17	31.83	32.20	32.20	32.40	32.30	31.97	32.50
9..........	31.83	32.33	32.50	32.17	32.40	32.70	31.20	32.07	31.77	31.77	32.07	32.37	32.30	31.93	32.50
10..........	31.23	32.03	32.43	32.20	32.43	32.83	30.73	31.73	31.80	31.20	31.73	32.37	32.30	31.97	32.43
11..........	32.00	32.27	32.30	32.00	32.37	32.67	31.13	31.70	31.50	31.90	31.93	32.23	32.17	31.77	32.33
12..........	32.10	32.30	32.35	32.05	32.35	32.70	31.45	31.95	31.55	32.20	32.10	32.30	32.25	31.85	32.35
13..........	32.13	32.40	32.40	32.07	32.47	32.77	31.60	32.03	31.67	32.30	32.20	32.37	32.23	31.80	32.47
15..........	32.20	32.35	32.60	32.15	32.50	32.85	31.80	32.10	31.75	32.40	32.35	32.40	32.30	31.90	32.40
16..........	31.53	32.33	32.67	31.77	32.43	32.83	31.03	32.10	31.83	31.63	32.20	32.53	32.03	31.90	32.47
17..........	30.33	31.17	32.17	29.90	31.03	32.37	29.60	31.17	31.70	30.57	31.40	32.30	30.40	31.37	32.37
18..........	30.73	31.87	32.33	30.70	31.90	32.47	29.77	31.07	31.50	30.87	31.60	32.27	30.33	31.13	32.37
19..........	30.00	31.60	32.30	30.00	31.80	32.55	29.45	31.20	31.45	30.30	31.35	32.25	29.40	30.65	32.35
20..........	31.97	32.50	32.33	32.27	33.00	33.03	31.20	31.77	31.53	31.67	31.97	32.30	31.30	31.43	32.30
22..........	40.10	39.30	38.13	40.00	39.40	38.50	34.53	32.13	31.63	35.57	32.53	32.33	32.10	31.53	32.23
24..........	35.33	36.57	37.23	35.57	36.40	37.27	34.13	34.73	34.27	36.47	37.13	37.70	32.40	31.80	32.33
25..........	32.80	33.60	34.17	32.70	33.60	34.30	32.60	33.43	33.40	33.60	34.10	34.80	32.30	31.93	32.40
26..........	31.80	32.83	33.27	30.87	32.27	33.07	32.33	33.27	33.13	32.67	33.27	33.70	32.27	31.90	32.37
27..........	30.70	31 90	32.53	28.47	29.73	31.53	32.17	32.93	32.80	31.70	32.70	33.17	32.27	31.87	32.37
Average...	**32.21**	**32.74**	**32.96**	**32.19**	**32.73**	**33.13**	**31.49**	**32.13**	**31.95**	**32.11**	**32.31**	**32.73**	**31.93**	**31.74**	**32.40**

TABLE 28.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, MARCH, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4′	6″	2″	4″	6″
1..........	29.27	29.73	30.77	29.00	29.90	30.93	30.67	32.43	32.30	29.33	30.80	32.07	30.70	31.70	32.37
2..........	31.50	32.07	32.20	32.10	32.27	32.37	31.47	32.37	32.27	31.40	31.57	32.13	31.87	31.67	32.33
3..........	28.30	29.67	30.47	29.07	30.33	31.70	29.10	32.10	32.03	28.97	30.47	31.67	29.37	30.60	32.37
4..........	29.47	30.37	30.20	29.83	30.77	31.80	29.63	31.83	31.90	29.53	30.43	31.43	29.93	30.60	32.27
5..........	30.50	31.13	31.43	31.13	31.97	32.33	29.97	31.53	31.60	30.57	31.07	31.60	30.73	31.00	32.23
6..........	31.63	32.03	32.07	31.77	32.13	32.33	31.07	31.80	31.60	31.43	31.53	31.83	31.63	31.13	32.17
8..........	32.03	32.23	32.30	31.90	32.23	32.33	31.43	31.03	31.73	31.70	31.90	32.07	31.80	31.87	32.20
9..........	31.47	31.90	32.30	30.83	31.70	32.30	31.43	32.07	31.70	31.57	31.67	32.07	31.60	31.47	32.17
10..........	32.07	32.33	32.27	31.87	32.23	32.33	31.83	32.17	31.73	32.33	32.07	32.17	32.17	31.57	32.13
11..........	32.13	32.40	32.30	32.23	32.30	32.43	31.90	32.17	31.80	32.40	32.27	32.20	32.20	31.63	32.13
12..........	34.27	34.37	34.10	34.63	34.63	34.63	31.57	32.13	31.83	32.70	32.27	32.17	32.13	31.63	32.13
13..........	38.73	37.33	36.17	37.73	36.63	36.10	34.40	33.90	32.70	34.40	33.27	32.40	32.13	31.63	32.13
15..........	38.10	37.73	37.23	37.93	37.67	37.30	37.40	37.03	36.00	37.60	36.90	36.50	32.80	31.67	32.17
16..........	35.90	35.97	35.67	36.33	36.20	36.07	35.00	35.53	35.00	35.77	35.53	35.53	32.37	31.70	32.17
17..........	34.00	34.23	34.73	34.87	34.87	35.37	32.70	34.47	34.07	33.47	34.17	34.40	32.20	31.77	32.20
18..........	38.30	37.13	36.20	38.70	37.87	36.93	35.50	35.63	34.70	35.63	35.37	35.17	32.17	31.67	32.17
19..........	39.27	38.37	37.47	39.50	38.80	37.97	37.87	37.17	35.97	38.00	36.77	36.30	32.23	31.70	32.17
20..........	40.00	38.97	38.00	39.63	39.13	38.30	38.57	37.40	36.27	38.67	37.50	36.97	32.47	31.70	32.20
22..........	36.03	35.77	35.53	36.00	35.83	35.73	34.43	34.70	34.17	35.60	35.23	35.13	32.27	31.80	32.23
23..........	40.43	39.27	38.13	40.43	39.47	38.43	37.93	36.87	35.47	38.43	37.13	36.37	32.37	31.70	32.27
24..........	40.30	39.37	38.30	40.03	39.33	38.40	38.03	37.07	35.80	38.57	37.40	36.83	32.83	31.73	32.23
25..........	39.93	40.30	40.07	40.10	40.43	40.43	39.17	39.20	38.10	39.87	39.43	39.00	33.67	31.67	32.20
26..........	33.47	34.50	35.33	33.47	34.43	35.53	32.07	34.37	34.53	37.87	34.80	35.53	32.27	31.90	32.30
27..........	35.70	34.83	35.17	35.43	34.80	35.43	32.80	33.87	33.63	33.87	34.40	34.50	31.83	31.80	32.27
29..........	30.27	31.70	32.50	29.83	31.33	32.63	30.67	32.43	32.70	31.60	32.70	33.50	31.20	31.97	32.33
30..........	31.33	31.67	32.00	30.23	31.03	31.97	30.20	31.60	32.03	30.70	31.97	32.50	31.60	31.77	32.30
31..........	32.60	32.53	32.70	32.63	32.77	33.23	31.50	32.13	32.03	32.17	32.30	32.60	31.80	31.83	32.30
Average...	**34.33**	**34.37**	**34.28**	**34.34**	**34.48**	**34.64**	**33.27**	**33.89**	**33.47**	**33.86**	**33.74**	**33.88**	**31.86**	**31.59**	**32.23**

TABLE 29.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, APRIL, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1..........	37.47	36.77	35.83	38.13	37.53	36.70	33.53	32.53	32.17	34.20	33.20	33.10	32.13	31.67	32.30
2..........	39.13	38.63	37.43	39.27	38.93	38.30	37.77	36.63	34.80	37.90	36.63	35.63	32.17	31.70	32.30
3..........	39.50	38.50	37.47	39.20	38.50	37.67	37.83	36.87	35.57	37.83	36.67	36.20	32.20	31.73	32.33
5..........	43.10	42.17	41.03	43.40	42.60	41.50	43.00	40.57	38.77	41.87	40.43	39.43	32.67	31.67	32.30
6..........	50.67	47.77	45.10	51.07	48.83	46.00	48.30	44.57	41.23	47.27	44.17	42.10	36.73	31.67	32.33
7..........	53.73	51.03	48.47	53.60	51.47	49.07	51.37	47.83	44.63	50.37	47.37	45.40	38.53	31.70	32.37
8..........	53.73	50.97	48.73	52.67	50.60	48.57	51.13	48.07	45.50	49.87	47.20	45.90	37.73	31.70	32.40
9..........	51.50	49.77	48.60	51.27	49.90	48.73	49.90	48.10	46.33	48.90	47.50	46.73	38.07	32.53	32.80
10..........	51.90	51.30	50.37	52.07	51.57	50.80	51.43	50.20	48.20	53.17	49.63	49.07	44.17	36.93	35.40
12..........	38.83	39.57	40.20	38.43	39.17	39.87	39.27	40.43	40.67	40.03	40.63	41.47	39.23	39.77	41.00
13..........	47.93	45.90	43.97	48.83	46.90	44.63	46.73	44.00	41.50	45.57	43.20	41.80	44.53	40.77	40.40
14..........	53.60	50.43	47.83	53.77	51.50	48.93	50.47	47.13	44.30	50.37	47.13	45.27	47.90	43.83	42.77
15..........	55.37	53.47	50.67	55.57	53.83	51.77	53.37	50.27	46.77	52.57	49.73	47.87	49.73	45.70	44.33
16..........	51.00	50.17	49.60	51.10	50.80	50.13	50.13	49.37	47.60	49.90	48.70	48.43	49.10	47.23	46.77
17..........	57.70	54.80	51.30	57.90	55.60	52.43	55.97	51.27	47.03	54.03	50.27	47.70	51.20	46.07	44.87
19..........	65.00	61.87	58.50	64.97	62.57	59.53	63.40	58.57	53.67	61.73	57.73	54.70	57.27	51.60	49.13
20..........	64.77	62.33	59.83	64.40	62.63	63.73	57.43	60.30	56.13	62.10	59.10	56.87	57.97	53.93	51.70
21..........	57.17	56.63	55.63	56.83	56.20	55.67	57.13	56.00	53.73	55.77	54.47	53.67	52.47	51.27	51.13
22..........	61.67	59.10	56.67	62.20	60.03	57.50	60.53	57.00	53.63	59.20	56.30	54.27	57.23	52.97	51.40
23..........	65.77	69.10	64.83	66.27	70.27	66.43	71.83	65.67	59.73	69.53	64.90	60.87	67.07	60.33	55.87
24..........	76.43	73.17	69.23	76.23	73.67	70.33	75.97	70.17	64.33	73.33	68.67	65.30	70.10	64.30	60.27
26..........	76.87	74.57	71.67	76.20	74.23	71.83	76.87	72.73	67.87	74.50	70.57	68.40	71.43	67.13	64.23
27..........	74.77	73.10	70.80	74.17	52.60	70.70	75.33	71.93	67.77	73.20	69.13	68.10	69.90	68.50	64.60
28..........	72.93	72.60	70.33	73.47	72.10	70.30	74.70	71.73	67.63	72.43	69.67	68.00	69.83	66.63	64.77
29..........	66.10	66.50	66.00	66.63	66.30	66.03	67.67	67.30	64.97	65.23	64.60	64.60	63.57	63.37	63.53
30..........	53.63	55.23	56.67	54.23	55.17	56.60	55.43	57.43	57.87	53.83	55.27	56.80	54.40	56.70	59.50
Average...	**56.16**	**54.82**	**52.95**	**56.22**	**54.36**	**53.60**	**55.25**	**52.95**	**50.10**	**54.41**	**52.03**	**50.69**	**49.90**	**46.59**	**45.80**

TABLE 30.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, MAY, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1..........	58.53	57.23	55.93	58.03	56.97	56.03	58.43	56.97	55.00	56.73	55.03	54.60	56.60	54.93	55.83
3..........	52.60	53.93	54.73	52.73	53.70	54.83	53.77	55.33	55.37	53.13	53.10	54.87	53.57	54.83	56.77
4..........	48.53	49.80	50.57	46.27	49.07	50.07	49.90	51.17	51.13	49.73	49.70	51.17	50.60	51.50	53.40
5..........	53.33	52.93	52.30	53.63	53.27	52.70	53.33	52.73	51.00	53.20	51.53	51.57	53.83	52.13	52.13
6..........	59.40	57.80	55.93	60.80	59.23	57.37	57.97	55.57	52.83	58.17	55.43	54.17	54.53	54.40	53.07
7..........	55.63	56.00	56.00	56.53	56.53	56.60	56.13	55.90	54.33	56.03	55.77	55.47	56.70	55.93	55.30
8..........	52.30	53.07	53.17	52.83	53.33	53.63	52.70	52.97	51.87	52.93	52.17	52.77	53.70	53.13	53.47
10..........	60.43	57.67	54.90	61.67	59.37	56.67	56.90	53.97	50.80	57.10	53.90	52.07	53.77	52.43	50.83
11..........	66.70	63.63	60.50	67.07	64.77	61.77	64.07	59.57	55.27	62.93	58.40	56.50	60.73	56.07	53.77
12..........	70.43	67.63	64.53	70.53	68.40	65.73	68.17	64.20	59.87	67.07	63.17	60.67	64.27	59.80	57.00
13..........	67.13	65.17	63.30	66.73	65.20	63.80	65.10	63.43	60.47	64.70	62.10	60.93	63.50	60.20	58.67
14..........	69.23	67.17	64.37	68.43	66.70	64.63	66.77	63.87	60.87	69.37	62.60	61.00	63.30	60.20	58.57
15..........	62.53	61.60	60.67	61.60	61.23	60.30	60.77	60.60	58.90	60.07	58.57	58.50	58.23	57.07	57.70
17..........	49.67	50.23	50.57	50.20	50.33	50.57	49.43	51.07	50.77	50.47	50.27	51.00	50.73	50.87	52.47
18..........	48.03	47.90	48.13	47.73	47.67	47.63	47.30	48.10	47.77	48.30	47.43	48.20	48.23	47.77	49.57
19..........	57.67	55.17	52.80	58.53	56.33	54.10	54.00	52.00	49.40	54.73	50.90	50.30	54.20	50.40	49.30
20..........	48.90	49.53	50.00	48.77	49.27	49.90	47.77	49.67	49.23	48.87	48.23	49.63	49.00	49.20	50.60
21..........	61.10	59.40	57.17	62.77	61.17	58.97	58.87	56.37	52.90	59.60	56.10	54.43	59.70	54.67	52.03
22..........	56.93	56.13	58.80	57.67	56.77	56.10	55.43	54.50	52.97	55.27	53.03	53.93	55.47	53.97	53.70
24..........	62.97	64.70	62.70	67.30	65.67	53.87	54.93	62.13	58.83	63.80	61.03	59.57	63.47	63.07	57.37
25..........	62.70	62.17	61.40	62.97	62.47	61.90	62.13	61.13	58.97	61.53	60.10	59.60	61.63	59.63	58.50
26..........	57.77	57.93	57.93	58.43	58.53	58.37	57.47	57.67	56.70	57.33	56.87	57.27	58.20	57.57	57.97
27..........	57.60	56.27	55.00	57.10	56.10	55.00	55.57	54.23	52.23	55.13	53.27	52.60	55.63	52.93	53.53
28..........	56.03	56.20	54.97	52.40	55.17	55.03	54.83	54.17	52.70	54.47	53.10	53.17	54.40	53.10	53.67
29..........	55.37	55.40	55.17	55.87	55.57	55.33	55.13	54.87	53.40	55.17	54.27	54.10	55.87	54.23	54.27
31..........	70.40	67.23	63.97	70.47	68.07	65.17	64.17	63.27	59.10	66.13	61.90	59.60	63.90	59.27	56.90
Average...	59.54	57.77	56.76	58.74	58.11	56.78	56.96	56.37	54.34	57.39	55.31	54.92	56.69	54.97	54.48

TABLE 31.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JUNE, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1..........	70.63	68.70	66.23	70.70	69.13	67.03	68.87	65.83	62.00	67.40	64.03	62.23	62.00	61.37	59.17
2..........	61.10	61.83	62.20	61.00	61.53	62.10	61.30	62.10	61.03	60.70	60.43	61.07	61.13	60.57	60.53
3..........	59.40	59.47	59.33	59.30	59.30	59.30	58.67	59.43	58.17	59.63	58.53	58.77	60.03	58.90	59.03
4..........	73.50	70.30	66.70	74.23	71.63	68.47	70.47	66.47	61.97	70.10	65.20	63.03	69.07	63.47	60.50
5..........	75.07	72.37	69.43	75.00	72.90	70.50	73.27	69.30	64.97	71.97	67.97	65.30	69.10	64.93	62.77
7..........	70.07	71.83	71.27	71.93	71.80	71.63	72.50	71.63	69.47	71.77	70.67	69.90	71.23	69.67	67.63
8..........	64.27	64.23	63.43	66.13	64.90	64.03	64.27	64.03	62.43	64.63	63.23	63.17	65.73	63.70	63.67
9..........	......	61.17	61.07	61.77	61.23	61.17	61.13	61.43	60.47	61.10	60.33	60.90	62.43	61.60	62.47
10..........	......	57.63	57.77	57.23	57.07	57.30	57.10	57.97	57.27	57.27	56.87	57.50	57.23	57.50	59.13
11..........	......	66.90	64.00	71.27	68.70	65.87	67.87	64.27	60.53	67.70	63.87	61.60	68.30	62.57	60.40
12..........	.....	70.37	67.63	73.33	71.33	68.93	71.17	67.80	63.67	70.33	66.70	64.40	69.57	64.90	62.77
14..........	66.17	65.43	64.67	66.60	65.50	64.97	64.90	64.40	62.80	65.13	63.90	63.70	65.30	63.90	63.87
15..........	67.33	66.37	64.83	69.03	67.50	65.63	66.40	64.87	62.50	67.03	64.17	63.47	67.50	63.90	63.20
16..........	62.70	63.70	64.17	63.10	63.70	64.53	62.67	63.97	62.43	63.87	63.60	63.60	63.77	63.83	63.47
17..........	71.00	69.37	67.00	75.13	72.77	69.77	69.27	66.93	63.63	67.00	66.10	64.97	70.53	65.70	63.67
18..........	66.90	65.97	64.77	68.07	66.87	66.13	64.80	64.13	62.37	65.57	63.37	63.37	65.27	63.73	63.97
19..........	65.97	65.73	65.13	68.87	67.77	66.70	65.30	65.20	63.43	65.83	64.43	63.97	67.20	65.20	65.07
21..........	68.13	67.30	66.37	72.63	68.30	67.63	66.57	65.97	63.83	67.23	65.70	64.90	67.20	64.70	64.67
22..........	70.63	69.43	67.77	72.60	71.13	69.40	69.43	67.63	64.57	69.57	67.00	65.60	67.87	65.33	64.53
23..........	71.73	69.83	67.63	72.63	70.67	68.63	70.80	67.77	64.33	69.60	66.63	64.77	69.50	64.67	63.37
24..........	66.47	65.47	64.73	66.67	65.57	64.87	65.43	64.80	63.27	65.03	63.23	63.47	64.33	62.90	63.40
25..........	75.13	72.23	69.10	75.30	72.83	69.87	72.93	69.10	64.90	72.43	68.03	65.47	72.60	65.90	63.70
26..........	79.50	76.47	73.20	78.40	76.10	73.60	76.73	73.03	68.37	76.07	71.97	68.93	75.47	69.57	66.30
28..........	81.50	78.70	75.90	79.43	77.47	75.47	78.90	75.87	71.87	78.20	74.67	72.37	76.23	71.97	69.63
29..........	70.10	69.60	69.50	69.93	69.50	69.40	68.33	69.77	68.80	69.43	68.73	68.87	69.37	68.33	69.00
30..........	77.77	75.30	72.83	79.17	77.00	74.53	75.17	73.20	69.30	76.00	72.67	70.33	77.60	71.87	68.80
Average...	**c69.78**	**67.92**	**66.79**	**69.98**	**68.55**	**67.22**	**67.86**	**66.42**	**63.79**	**67.84**	**65.46**	**64.45**	**67.53**	**64.65**	**63.65**

c The average of 22 days only instead of 26 of which remaining depths and soils were taken.

TABLE 32.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JULY, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1..........	77.57	75.93	74.60	77.70	76.50	75.60	75.27	74.90	71.77	76.60	74.00	72.63	75 33	74.13	72.37
2..........	74.77	73.90	72.77	77.77	76.33	74.77	73.23	72.97	70.50	75.03	72.63	71.70	74.97	72.20	71.17
3..........	75.97	73.93	72.27	76.73	75.17	73.63	72.00	71.87	69.27	73.77	71.10	70.47	72.60	70.93	70.47
5..........	62.20	62.50	63.00	63.20	63.45	63.70	60.25	63.25	62.75	63.30	62.90	63.75	61.90	63.20	64.90
6..........	71.47	69.43	67.20	72.63	70.77	68.73	66.70	66.70	63.77	70.10	66.57	65.40	66.67	63.93	63.53
7..........	64.83	64.97	65.40	64.53	64.53	65.30	61.33	65.10	64.27	64.83	64.13	65.43	64.03	64.50	65.13
8..........	71.10	69.30	67.43	74.10	72.17	69.83	67.30	67.77	64.67	69.70	66.47	65.80	69.03	65.43	64.17
9..........	78.63	75.47	72.27	79.67	77.20	74.63	73.50	72.07	67.77	73.87	69.47	68.17	72.63	68.07	65.77
10..........	81.43	78.87	76.17	81.57	79.60	77.43	78.30	75.50	71.30	76.87	73.93	71.40	76.97	71.90	69.03
12..........	83.73	81.20	78.50	83.43	81.53	79.37	81.03	78.30	74.33	79.70	......	74.30	81.00	75.30	73.07
13..........	85.90	82.83	79.67	84.57	82.53	80.23	83.00	79.70	75.50	81.03	......	75.33	82.53	77.03	74.47
14..........	81.60	80.10	78.43	81.03	79.90	78.57	78.67	78.37	75.47	78.40	......	75.10	80.03	76.93	75.57
15..........	75.23	74.70	74.37	75.23	74.90	74.70	73.33	74.87	73.03	75.13	......	73.53	76.30	74.90	74.30
16..........	80.43	78.47	76.57	82.13	80.33	78.23	77.53	77.10	73.83	80.30	77.33	75.10	80.73	76.50	74.57
17..........	84.70	82.07	79.43	85.07	83.30	80.97	81.13	79.67	75.77	82.13	79.10	76.80	82.97	78.27	75.90
19..........	73.63	73.57	73.00	74.27	74.03	73.47	72.20	73.60	71.80	75.47	73.90	72.90	75.13	73.60	73.50
20..........	73.23	71.77	70.80	73.77	72.43	71.50	70.73	71.27	69.40	73.47	71.90	71.03	71.60	70.67	70.93
21..........	69.37	70.27	70.17	68.97	69.80	70.43	68.40	70.53	68.63	70.27	70.30	69.67	69.83	68.97	69.03
22..........	75.37	72.97	71.07	76.10	74.07	72.07	72.67	71.73	68.50	74.67	72.00	69.83	72.93	69.73	67.57
23..........	80.63	77.80	75.10	80.77	78.80	76.40	77.03	75.03	71.23	77.23	74.37	72.17	77.00	72.30	70.20
24..........	75.23	74.33	73.40	75.23	74.60	74.00	72.80	73.07	70.87	73.10	72.07	71.20	73.33	71.57	70.87
26..........	75.73	73.73	72.23	76.77	75.13	73.53	73.67	72.67	70.07	75.17	72.93	71.43	74.90	71.93	70.23
27..........	68.30	68.43	68.60	68.03	68.23	68.67	67.27	68.87	67.97	68.43	68.47	68.70	68.63	68.77	69.50
28..........	71.07	70.27	69.67	71.10	70.60	70.23	69.50	69.90	68.13	70.67	69.73	69.00	71.23	69.77	68.60
29..........	72.53	71.00	69.60	72.40	71.20	70.20	70.73	69.93	67.80	71.87	69.87	68.90	72.27	69.53	68.30
30..........	79.33	77.33	75.43	80.40	78.70	76.90	76.97	75.53	72.17	78.97	76.13	73.87	79.43	75.17	69.93
31..........	80.07	77.73	75.70	79.87	78.20	76.63	77.60	75.93	72.80	78.77	76.20	74.37	79.57	75.60	71.43
Average...	**75.70**	**74.18**	**72.70**	**76.18**	**74.96**	**73.69**	**73.41**	**72.82**	**70.12**	**74.39**	**c71.55**	**71.04**	**74.20**	**71.51**	**70.16**

cAverage of 23 days only.

TABLE 33. AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, AUGUST, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
2	73.63	73.10	73.37	73.00	72.63	73.23	72.57	73.50	72.93	73.17	73.33	73.77	74.00	74.53	75.17
3 .	72.47	71.67	71.00	72.27	71.67	71.27	71.63	71.30	69.73	72.60	71.33	70.47	73.17	71.77	72.03
4 ...	68.70	68.50	68.40	68.77	68.67	68.73	68.00	68.67	67.77	69.07	68.63	68.73	69.33	69.37	70.27
5 ..	62.20	62.77	63.63	61.70	62.30	63.33	61.77	63.83	64.00	62.87	63.73	64.70	62.93	64.77	67.00
6	67.53	66.37	65.57	67.67	66.73	65.97	65.97	65.57	63.87	67.07	65.63	64.87	66.97	65.20	65.30
7	68.33	67.10	66.23	68.43	67.80	67.03	66.43	66.03	64.20	67.47	66.20	65.33	67.57	65.50	64.37
9 ...	77.97	75.50	73.23	79.30	77.23	74.97	73.90	71.80	68.67	76.43	73.37	71.10	76.43	71.57	69.30
10	80.33	78.03	75.60	81.03	79.17	77.07	76.37	74.10	70.60	78.43	75.37	72.93	78.63	73.17	70.67
11	69.03	69.20	69.87	68.53	68.73	69.53	67.40	68.80	68.33	68.63	68.97	69.53	68.30	68.97	70.40
12........	66.93	66.87	67.13	66.77	66.70	66.93	66.20	67.03	66.23	67.23	67.03	67.17	67.20	67.03	67.87
13	73.00	71.43	70.17	74.07	72.73	71.37	70.87	69.80	67.33	71.93	70.00	68.63	71.87	68.97	67.40
14	70.17	69.33	68.80	70.30	69.80	69.37	68.83	68.67	67.00	69.73	68.70	68.13	69.80	68.23	67.47
16	76.60	74.90	73.20	77.77	76.33	74.67	73.73	72.30	69.63	74.87	72.60	70.93	74.90	71.43	68.87
17.........	68.83	68.60	68.63	70.30	69.70	69.53	67.70	68.53	67.50	68.83	68.53	68.50	68.43	68.30	68.77
18..........	71.80	69.73	68.03	72.90	71.27	69.50	68.67	67.47	65.10	69.07	67.07	65.90	68.33	65.77	68.47
19.........	76.03	73.47	71.20	76.57	74.87	72.73	72.87	70.47	67.13	73.27	70.73	68.20	72.80	68.37	66.30
20.........	70.50	69.90	69.10	70.50	69.97	69.50	68.70	68.23	66.57	68.97	68.07	67.43	68.67	67.20	66.90
21	65.00	65.17	65.60	64.70	61.93	65.50	64.43	65.27	64.70	65.23	65.23	65.57	65.20	65.33	66.37
23.........	74.73	72.80	70.67	76.40	74.67	72.80	72.30	70.03	66.97	72.57	70.03	68.20	72.33	68.23	66.60
24........	71.83	71.23	70.57	72.30	72.00	71.67	70.40	70.03	68.17	70.73	69.97	69.27	70.80	69.37	67.90
25..........	68.00	66.97	66.43	68.30	67.50	66.77	66.13	65.67	64.60	66.47	65.57	65.40	66.03	65.07	65.93
26	68.63	67.90	66.97	69.17	68.70	67.97	66.77	66.33	64.30	67.33	66.23	65.30	67.77	65.43	64.77
27..........	68.27	66.83	65.40	67.97	66.90	65.90	65.60	64.50	62.53	66.30	64.43	63.40	66.03	63.27	63.20
28..........	70.70	68.93	67.03	70.50	69.23	67.63	67.73	66.07	63.43	68.47	66.10	64.50	68.53	64.47	63.57
30..........	65.27	64.23	63.33	65.33	64.50	63.70	63.10	62.57	61.27	63.93	62.57	62.10	64.03	62.10	62.67
31..........	66.57	65.07	63.67	66.23	65.17	64.07	63.87	62.80	60.83	64.60	62.83	61.70	64.63	61.47	61.43
Average...	**70.50**	**69.45**	**68.58**	**70.80**	**70.00**	**69.26**	**68.54**	**68.05**	**66.28**	**69.44**	**68.17**	**67.38**	**69.42**	**67.50**	**67.28**

TABLE 34.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, SEPTEMBER, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1..........	70.17	68.23	66.23	70.07	68.67	67.03	67.73	65.50	62.73	68.10	65.70	63.90	68.20	63.97	62.77
2..........	73.33	71.13	68.77	73.00	71.43	69.53	70.73	68.07	64.93	71.13	68.27	66.20	71.50	66.57	64.50
3..........	72.03	70.87	69.43	71.83	70.93	69.90	70.20	68.63	66.10	70.40	68.67	67.20	70.60	67.40	66.30
4..........	70.27	69.17	68.37	70.10	69.33	68.77	69.40	67.93	65.67	68.23	67.20	66.60	69.23	67.13	66.60
6..........	64.10	64.13	64.27	63.93	64.13	64.43	64.30	64.40	63.50	64.43	64.40	64.40	64.50	64.23	64.80
7..........	69.97	68.03	66.47	70.20	68.67	67.27	69.10	66.60	64.23	68.83	66.63	65.27	69.13	65.53	64.77
8..........	74.33	72.67	70.80	75.00	73.60	72.23	73.63	70.97	67.93	73.10	70.90	69.07	74.13	69.70	67.77
9..........	69.47	69.23	69.10	70.70	70.47	70.40	69.60	69.37	67.83	69.20	68.93	68.60	70.27	69.50	69.07
10..........	67.20	67.23	66.93	67.63	67.83	67.87	67.47	67.37	65.63	66.90	66.57	66.10	66.80	66.33	66.70
11..........	71.23	69.60	68.00	71.30	70.17	68.83	70.83	68.37	65.93	70.40	68.17	66.83	71.23	67.40	66.40
13..........	76.63	74.97	73.20	79.57	77.93	75.83	76.13	73.70	70.37	75.80	73.57	71.63	75.67	72.67	70.20
14..........	80.77	78.73	76.37	82.40	80.93	78.90	80.37	77.10	73.20	79.30	76.63	74.20	78.33	74.43	72.10
15..........	76.90	76.00	75.23	77.40	76.73	76.23	76.90	75.60	73.20	75.73	74.80	73.90	76.00	74.10	73.13
16..........	75.47	74.43	73.53	76.43	75.63	74.73	74.80	73.53	71.60	75.30	73.80	72.57	75.33	73.03	72.10
17..........	72.60	72.10	71.33	73.03	72.57	72.00	72.60	71.60	69.83	72.53	71.50	70.97	73.70	71.77	71.43
20..........	67.17	67.17	67.30	67.33	67.60	67.83	67.63	67.60	66.37	67.13	67.07	66.97	66.77	67.13	67.83
21..........	56.67	57.60	58.90	57.07	57.80	58.83	57.37	59.17	59.60	57.47	58.70	60.03	58.17	59.90	62.73
22..........	60.70	59.93	58.27	61.33	61.27	60.13	60.43	59.47	57.93	59.63	58.90	58.33	59.87	57.93	58.97
23..........	60.90	59.93	59.33	61.60	61.00	60.27	60.57	59.47	58.00	59.93	58.90	58.33	58.47	57.27	58.47
24..........	69.97	68.07	66.00	71.00	69.77	67.90	69.33	66.20	62.93	68.00	65.50	63.53	68.37	63.63	61.53
25..........	69.87	68.40	66.87	70.77	69.73	68.30	69.50	67.13	64.37	68.20	66.23	64.73	68.30	64.73	63.30
27..........	52.63	53.10	54.23	52.33	52.27	53.40	53.27	54.20	54.97	53.13	53.80	55.30	52.27	54.57	57.73
28..........	55.23	55.13	54.73	56.47	56.10	55.43	54.97	54.57	53.80	54.00	53.83	52.87	54.57	53.37	55.00
29..........	56.87	56.23	55.20	57.60	53.73	56.27	56.57	55.47	53.67	54.80	54.07	53.37	55.40	53.17	53.80
30..........	57.20	56.37	55.60	57.53	56.97	55.80	57.17	55.63	54.07	55.07	54.13	53.63	55.07	53.13	53.77
Average...	67.67	66.74	65.78	68.23	67.41	66.73	67.22	65.90	63.94	66.67	65.47	64.58	66.88	64.74	64.47

TABLE 35.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, OCTOBER, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1..........	52.97	53.53	53.20	52.70	53.33	54.17	53.10	53.83	53.60	52.97	53.37	53.77	52.87	53.30	54.50
2..........	59.60	58.07	57.37	59.77	59.00	58.10	58.67	57.10	55.13	58.40	56.87	55.83	59.13	55.93	55.07
4..........	61.03	61.07	60.83	61.03	61.33	61.40	60.93	60.53	59.00	60.67	60.33	59.63	61.60	60.00	59.13
5..........	53.43	54.40	55.13	53.30	54.03	55.00	53.43	54.43	54.47	52.93	53.87	54.83	54.07	54.97	56.70
6..........	53.20	53.63	53.90	52.87	53.47	53.37	52.97	53.40	52.87	52.23	52.67	53.10	53.17	52.97	54.13
7..........	48.97	50.37	51.27	48.93	50.07	51.20	49.23	50.50	50.50	49.27	49.87	50.57	49.27	50.20	52.10
8..........	44.40	45.73	46.80	43.80	44.93	46.27	44.50	46.33	46.50	44.77	46.37	47.23	44.67	46.47	49.43
9..........	45.07	45.90	46.30	45.27	45.70	45.97	45.03	45.60	45.93	44.50	45.00	45.70	45.27	45.90	47.33
11..........	56.37	54.53	52.67	57.40	56.13	54.10	54.73	52.07	49.30	53.80	51.47	49.60	52.73	48.57	47.80
12..........	46.97	55.47	54.33	57.43	56.60	55.30	55.50	53.70	51.70	54.60	53.13	52.03	53.97	50.87	50.40
13..........	56.33	55.43	54.73	56.50	55.87	55.33	55.50	54.30	52.77	55.53	54.13	53.30	55.33	52.30	52.03
14..........	56.10	55.83	55.47	56.07	56.07	55.97	55.83	55.23	53.73	55.90	55.27	54.63	55.77	53.87	53.47
15..........	58.27	57.50	56.53	58.57	58.13	57.23	57.50	56.23	54.37	56.77	55.77	55.03	58.10	55.00	54.00
16..........	56.37	55.03	53.70	56.60	55.63	54.30	55.37	53.50	52.00	54.10	52.80	52.10	55.17	52.30	52.30
18..........	58.33	57.93	57.43	58.47	58.50	58.13	58.13	57.23	55.47	58.13	57.07	56.30	58.40	56.30	55.37
19..........	56.47	56.27	55.93	56.20	56.40	56.10	56.27	55.77	54.40	56.13	55.67	55.20	56.80	54.97	54.80
20..........	58.47	57.50	56.43	58.83	58.10	57.20	57.57	56.23	54.33	57.43	56.07	55.17	57.60	54.80	54.27
21..........	54.70	54.17	53.80	55.03	54.37	54.37	53.97	53.40	52.57	53.50	53.23	53.03	52.57	52.27	53.30
22..........	53.63	52.83	51.80	53.63	52.97	51.93	52.43	51.70	50.40	51.60	51.33	50.83	50.33	49.40	50.77
23..........	51.27	51.23	51.10	50.93	51.03	51.13	50.53	50.57	49.73	49.73	49.80	49.93	49.47	48.97	50.20
25..........	54.17	53.13	52.17	54.47	53.87	53.00	52.93	51.60	49.77	52.13	50.83	49.87	51.83	49.10	49.13
26..........	50.60	50.43	50.27	50.60	50.70	50.60	49.87	49.67	49.13	49.23	49.07	49.03	48.70	48.03	48.90
27..........	51.57	50.77	50.00	51.57	51.20	50.57	50.47	49.50	47.70	49.57	48.73	48.07	49.50	47.37	47.93
28..........	53.80	52.40	50.37	54.10	53.13	51.70	52.30	50.53	48.63	51.53	50.03	48.93	51.20	48.13	48.20
29..........	51.77	51.03	50.53	51.77	51.53	50.87	50.70	49.90	48.93	50.03	49.27	49.03	49.43	48.23	48.57
30..........	51.37	50.63	50.00	51.60	51.03	50.57	50.37	49.53	48.20	49.33	48.83	48.43	49.40	47.73	48.17
Average...	53.66	53.65	53.16	54.13	53.97	53.61	53.38	52.78	51.58	52.88	52.34	51.97	52.94	51.46	51.85

TABLE 36.—AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, NOVEMBER, 1915.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1..........	53.70	52.73	52.30	53.50	53.03	52.83	52.20	51.57	50.50	51.70	50.47	50.80	51.03	50.17	50.17
2..........	45.37	46.53	47.63	45.30	46.30	47.57	45.27	47.07	47.73	45.10	46.23	47.67	45.03	47.83	49.10
3..........	42.90	43.33	43.73	42.70	43.17	43.63	42.67	43.30	43.17	41.90	42.47	43.13	41.37	42.13	44.90
4..........	48.63	47.83	47.00	48.83	48.30	47.63	47.50	46.57	45.37	47.00	46.10	45.47	46.80	44.83	45.20
5..........	42.97	43.70	44.30	42.50	43.27	44.13	42.60	43.70	43.80	42.63	43.27	44.00	42.20	43.23	45.13
6..........	43.43	43.03	42.73	43.30	43.00	42.73	42.27	41.97	41.57	42.00	41.73	41.80	40.73	40.40	42.60
8..........	56.07	54.60	52.87	56.97	55.97	54.50	54.90	52.67	49.87	54.60	52.50	50.63	54.10	50.03	47.70
9..........	46.17	46.33	46.70	46.10	46.60	47.17	46.10	46.53	46.20	45.47	42.57	46.23	45.37	45.60	46.60
10..........	41.30	41.47	42.47	40.80	41.33	42.20	41.53	41.63	42.23	40.87	41.47	42.27	39.50	40.93	43.57
11..........	53.23	51.40	49.77	53.33	51.87	50.40	51.60	49.20	47.00	51.77	49.43	48.00	50.63	46.80	45.63
12..........	43.43	44.40	45.40	43.03	44.10	44.03	43.97	45.60	45.73	44.10	45.60	46.10	44.17	45.33	46.60
13..........	40.30	40.93	41.17	40.00	40.63	41.23	40.77	41.60	41.67	40.70	41.27	42.23	40.53	41.00	43.13
15..........	34.67	35.97	37.17	34.23	35.27	36.67	34.70	36.83	37.83	35.13	36.57	37.87	35.57	37.57	40.10
16..........	33.73	35.67	35.77	32.83	33.87	35.17	33.37	35.17	36.17	33.47	34.80	36.13	33.97	36.07	38.50
17..........	37.97	37.80	37.67	37.57	37.60	38.03	37.13	37.40	37.07	38.47	38.17	37.90	34.87	35.70	37.53
18..........	37.83	38.03	37.97	37.67	37.90	38.00	37.37	37.47	37.17	38.00	37.83	37.70	35.73	35.87	37.40
19..........	39.67	40.17	40.57	39.63	40.20	40.80	39.40	40.10	39.83	39.97	40.33	40.53	38.93	39.07	39.53
20..........	36.77	37.63	38.33	36.63	37.43	38.27	36.67	37.77	37.97	37.30	37.97	38.27	36.63	37.40	38.70
22..........	32.87	33.93	34.80	32.53	33.63	34.70	33.30	34.67	35.27	33.47	34.40	35.40	33.63	34.87	37.10
23..........	32.43	33.43	34.13	32.13	33.07	34.00	32.60	33.97	34.47	33.07	33.90	34.67	33.27	34.23	36.07
24..........	34.70	35.00	35.27	33.60	34.37	35.13	33.60	34.57	34.57	34.03	34.60	34.10	33.07	33.97	35.57
26..........	48.03	46.77	45.60	48.47	47.60	46.63	46.47	44.90	42.93	47.00	45.40	44.00	45.43	42.17	40.67
27..........	43.60	44.20	44.60	43.37	43.93	44.37	42.93	43.80	43.43	43.20	43.97	44.13	43.20	42.97	42.90
29..........	34.63	36.07	37.20	34.00	35.10	36.47	34.97	36.77	37.53	35.37	36.77	37.97	36.00	38.00	40.07
30..........	33.83	34.83	35.83	33.40	34.43	35.50	33.87	35.50	36.03	34.57	35.60	36.47	34.60	36.10	38.00
Average...	**41.37**	**41.67**	**41.87**	**41.14**	**41.52**	**41.91**	**40.95**	**41.45**	**41.25**	**41.07**	**41.18**	**41.58**	**40.50**	**40.73**	**41.94**

The daily and monthly average temperature of the second year, December 1, 1912 to November 30, 1913, are contained in Tables 1 to 12, inclusive. Beginning with the data of the month of December it will readily be seen that at the commencement of the month all the various types of soil at the three different depths had practically the same magnitude of temperature and had not yet reached the freezing point. The temperature at all three depths in every soil diminished gradually until December 12 when the upper 6-inch depth began to freeze. At this date the 6-inch depth of only the sand and gravel froze, that of the loam and clay froze one day later and peat ten days later. It will be noted, however, that while the peat at the 6-inch depth froze ten days later than that of the other soils its temperature during this time was only a few tenths of a degree higher. The temperature at the 6-inch depth of all the soils remained at or slightly below 32°F until January 3, when it rose in all of them a few tenths of a degree but it fell again at or below 32°F on January 29. Between February 4 and 14 the temperature at the 6-inch depth of all soils was several degrees below zero and on February 13 reached its minimum for the winter. At this date the average temperature of the various soils at this upper depth was as follows: gravel 22.43°, sand 19.60°, loam 23.30°, clay 23.93°, and peat 20.50°F. It is of great interest, therefore, to note that all these diverse classes of soil had practically the same average temperature during this period of cold weather in spite of their great difference in heat conductivity, water content, etc.

The air temperature on February 13 when the lowest temperature was reached, was 3° F.

While the 6-inch depth of all the different types of soil began to freeze about Dec. 12 and its temperature tended to remain at or near the freezing point, the 12 and 18-inch depths of all these soils did not really begin to freeze until the commencement of February when the extreme cold weather came. The 12-inch depth of the gravel and sand froze February 3, that of loam, clay and peat on February 5, or two days later; while the 18-inch depth of the various soils froze as follows: gravel February 6, sand February 8, clay February 10, loam February 11, that of peat did not completely freeze, its temperature remaining a few tenths of a degree above 32° F. throughout the rest of the winter.

It is remarkable to note that the temperature of the 12-inch and as well as that of the 18-inch depths attained its minimum degree practically simultaneously with the 6-inch depths. Yet when this minimum was reached at all three depths the difference or gradient of temperature between the 6 and 18-inch depths was very marked, being in most cases close to 12°F. In other words, when the temperature of the 6-inch depth reached its lowest degree, and it was about 20° F, the corresponding minimum of the 18-inch depth, which occurred on the same day, was about 32°F, or a gradient of 12°F.

The temperature at the 6-inch depth remained considerably below 32°F from February 4 to 20 and then it rose and tended to stay at about 32°F. When the other two depths froze their temperature also tended to remain at about 32°F. Hence the upper 18-inch layer of the soil had almost the same temperature and consequently had no gradient.

The temperature of the entire upper 18-inch layer remained at the freezing point until thawing began. The first thawing occurred on March 19. At this date the gravel and sand thawed completely down to the 18-inch depth—in a single day—while only the 6-inch depth of the loam and clay thawed on this date and that of the peat did not show any signs of thawing. At the 12 and 18-inch depths only clay commenced to thaw by March 26. The process of thawing, however, was only of short duration as on March 26 the air temperature fell very low and the upper 6-inch depth began to freeze again. On March 31, however, the air temperature went up again and the soil temperature commenced to rise accordingly. On April 1 the 12-inch depth of the loam and the 6-inch depth of the peat began to thaw. The 12-inch depth of the peat did not show signs of thawing until April 15. The temperature of the 18-inch depth of the loam began to rise slightly above 32°F by March 8—long before the actual thawing at the surface of the various soils had taken place—so that by the time the other two depths had thawed it was by a few degrees higher than that of the 12-inch depth.

This rising of temperature at the 18-inch depth of the loam before complete thawing had taken place at the above depths is extremely interesting and goes to indicate that some heat comes to the surface from the lower and warmer depths of the earth. This fact finds confirmation in all the other soils and especially in peat. The 18-inch depth of the latter did not completely freeze but its temperature remained a few tenths of a degree above 32°F. By the middle of March, however, its temperature began to rise slowly but rather persistently so that by April 1, when the 6-inch depth of this soil commenced to thaw it was

34°F and by April 15 when the 12-inch depth began to thaw it had risen to 36.43°F.

These instances therefore, prove conclusively that an appreciable amount of heat traverses to the surface from the lower depths and tends to maintain a higher temperature there than would otherwise exist. It is perhaps partly on this account that after the soils freeze at the upper depths their temperature tends to remain at about the freezing point. At least a portion of the heat they lose at these upper depths is replenished by the heat coming from the lower depths. In the spring, however, when the air temperature begins to rise and the loss of heat from the soil is thereby diminished if not entirely stopped, the heat coming from the interior of the earth accumulates near the upper depths and causes a rise in temperature, just as the experimental data show. The amount, however, coming to the surface during a single day is undoubtedly small, partly because of the low heat conductivity of the soil, and partly on account of the small gradient of temperature existing at the adjacent depths.

Immediately upon complete thawing the temperature of the sand and gravel rose at once a few degrees above that of the clay and loam and several degrees above that of peat. In about three or four days, however, from the day that the actual thawing occurred, March 31, and freezing did not reoccur, the temperature of the sand, gravel, loam and clay reached about the same degree; that of peat, however, did not rise to the same magnitude until April 26 or about 27 days later. The reason for this is that its 12-inch depth did not begin to thaw until April 15 or almost one month after the corresponding depth of the other soils commenced to thaw. As soon as its entire frozen layer, however, had thawed then its temperature rose rapidly and approached that of the other soils in a short time.

The slow rate of thawing of peat and the rapid ascend of its temperature thereafter is extremely interesting and suggests very strongly that it is the latent heat of fusion of ice, which amounts to 80 calories per gram of water, which delays the warming of those soils possessing a large amount of water and not necessarily the high specific heat of the water in the liquid state. This inference finds strong confirmation in the fact that during the fall the peat which possesses the greatest total specific heat cools at the same rate and has practically identical temperature as the other soils.

The rapidity with which the clay and loam thawed and the rise of their temperature to the same magnitude as that of the sand and gravel in such a short time contradicts the exaggerated general belief that these soils possess a greatly lower temperature during the spring and therefore should be classed as cold soils.

Although by April 26 the average temperature of all the different types of soil approached the same magnitude it did not come any nearer between them, as it continued to rise in the subsequent months, until next September. Thus during the months of May, June, July and August it varied appreciably in the different types, being always highest in sand and gravel followed by loam, clay and peat, respectively. At some days the sand and gravel had as much as 10°F higher temperature than the peat at the 6-inch depth. This large difference, however, occurred only whenever the air temperature rose very high suddenly. As a monthly average during May and June the sand and gravel were about 4 or 5° F warmer than the peat at the 6-inch depth and only about 2°F warmer than the clay and loam, while as an average during the months of July and August the sand and gravel had only about 2 or 3°F higher temperature than peat and about 1 or 2°F greater than the clay and loam.

The higher average temperature of the sand and gravel over that of the clay, loam and peat during the spring and summer months, when their surface was not covered by a thin layer of sand as in the first year, is very noteworthy. It goes to show that those soils which possess a high moisture content are kept somewhat colder, during those months that the temperature rises, than the soils of low water-holding capacity, in spite of the darker color of some of the former. Evidently, these various soils lose different amounts of water through evaporation and consequently maintain different degrees of temperature.

That the factor of evaporation is the casual agent for this variation in temperature between the different classes of soil is shown by the fact that when the surface of these soils is covered by a thin layer of sand so that the evaporation of their water is more or less equalized, this variation disappears, and all the soils have practically equal magnitude of temperature as will be subsequently shown.

The highest daily average temperature for the year was reached between June 28 and 29 by all soils and at all three depths. The magnitude of temperature on June 28 for the 6, 12 and 18-in. depths respectively was as follows: gravel 87.83°, 81.30°, 78.70°; sand 85.03°, 79.87°, 75.67°; loam 85.83°, 79.00°, 73.37°; clay 84.40°, 78.33°, 73.87°; and, peat 80.37°, 74.73°, 70.97°F.

The highest monthly average temperature, however, occurred in July and ranged as follows for the 6, 12 and 18-inch depths, respectively: gravel 78.73°, 75.77°, 74.74°; sand 77.23°, 74.79°, 73.34°; loam 77.89°, 75.25°, 72.55°; clay 76.38°, 74.11°, 72.79°; and, peat 75.34°, 73.75°, 71.96°F.

The high temperature continued to prevail until August and then began to diminish. The differences in temperature between the various types of soil also commenced to decrease in August and by the middle of September they had almost entirely disappeared and the various soils then began to have identical degree of temperature. From this period on throughout the months of October and November or until the beginning of the third year in December, they cooled at about the same rate and maintained practically equal magnitude of temperature.

There were days, of course, when the average temperature of the different soils varied appreciably. But this occurred only whenever the air temperature changed very rapidly. On such occasions the peat would have a slightly higher temperature than the other soils if the air temperature went down rapidly, while the mineral soils and especially the sand and gravel would manifest a slightly higher temperature if the air temperature rose suddenly and rapidly. But as an average for the month all the soils were equally warm.

The same rate of cooling and equal magnitude of average temperature of the diverse classes of soil during the fall months occurred in all four years and are indeed remarkably interesting and contrary to the general popular belief. It has been popularly believed that since the sandy and gravelly types of soil contain a low percentage of water and consequently a small total heat capacity, they would cool at a greater rate and have a lower average temperature in the fall than such classes of soil as the loam, clay and peat which contain a relatively high water content and hence a large heat capacity.

This even rate of cooling and equal average temperature in the fall and winter months of the different types of soil both when their surface is covered with the thin layer of sand and when it remains uncovered indicate that there is no one intrinsic factor during this period which is sufficiently powerful to predominate and cause a variation in the temperature of these various soils.

The main and most important facts revealed by the daily and monthly march of the temperature of the different types of soil during the second year when they were not covered with a layer of sand may be summarized then as follows: (1) All these diverse types of soil froze at about the same time at the various corresponding depths, with peat at a slightly lower rate and had practically the same magnitude of temperature throughout the winter; (2) During a period of cold weather they all reached an equal minimum of temperature and at the same day at all three depths; (3) In the spring the sand and gravel thawed first, followed by loam and clay about one or two days later and peat several days later, down to the 18-inch depth; (4) Immediately upon complete thawing the average temperature of the sand and gravel rose a few degrees above that of the loam and clay and several of that of peat. In about three or four days, however, the temperature of the clay and loam rose to about the same magnitude as that of the sand and gravel, but that of the peat required considerably longer time to approach the same point; (5) The temperature of all the soils at all three depths continued to rise, after complete thawing, and almost attained the same magnitude but it did not become equal until in the fall. Up to this time it varied, being highest in the sand and gravel, followed in order by loam, clay and peat, respectively; (6) With the commencement of the fall the temperature of all the soils began to be equal and continued to be about the same throughout the fall months until the third year began in December.

It will now be seen how the foregoing results compare with those of the following or third year.

With the commencement of the third year, December 1, 1913 to November 30, 1914, all the different types of soil were again covered with a thin layer of sand as in the first year, December 1, 1911 to November 30, 1912. The daily and monthly average temperature of the third year are contained in Tables 13 to 24 inclusive.

An examination of these tables reveals (1) that all the different types of soil at all three depths did not freeze during the winter of the third year. Toward the last week of December the 6-inch depth of the various soils approached the freezing point but their temperature rose to about 33°F and prevailed at this point throughout the winter until in the spring when it began to rise. The temperature of the 12-inch depth remained throughout the entire winter at about 35°F and that of the 18-inch depth at about 36°F. The magnitude of the daily and monthly average temperature was remarkably close in all types at the respective depths.

(2) Signs of rise of temperature began to be manifested by March 14 but the real ascent did not commence until March 25. The temperature of the sand, gravel, loam and clay at the 6-inch depth rose almost simultaneously to about 40°F; that of the peat at the corresponding depth did not reach this point until March 31 or 6 days later. From this date on the average temperature of all the various soils tended to be equal. During the month of April it varied only about 1 or 2°F as a monthly average but as high as 7 or 8°F on certain individual days when the air temperature underwent rapid changes. During the months of May, June, July, August, September, October, and November, indeed up to the next cycle, the average temperature of all these distinct classes of soil was almost exactly the same. As a monthly average, the highest variation that occurred between any of them was only a little over 1°F. The peat especially at the 6-inch depth had a slightly higher temperature during the warmest part of the year than the other soils. The daily highest average temperature was attained on June 10. The magnitude on this date was as follows for the 6, 12 and 18-inch depths, respectively: gravel 81.90°, 76.50°, 73.93°; sand 81.47°, 75.00°, 70.97°; loam 80.93°, 74.23°, 67.97°; clay 80.47°, 73.77°, 70.07°; and, peat 81.03°, 72.27°, 67.20F. The monthly highest average temperature, however was reached in July with the following magnitudes: gravel 75.92°, 74.08°, 72.62°; sand 75.24°, 73.30°, 71.53°; loam 75.80°, 73.27°, 70.15°; clay 75.31°, 72.27°, 71.26°; and, peat 76.93°, 74.06°, 71.74°F for the 6, 12, and 18-inch depths, respectively.

The results of the spring and summer months of the third year, therefore agree almost perfectly with those of the first year, but disagree with those of the second year. As already seen in the second year the average temperature of the different soils varied appreciably during the spring and summer months, with the sand and gravel having the highest temperature followed by loam, clay and peat, respectively.

During the first and third year, however, all the diverse classes of soil were covered with a thin layer of sand, as already stated, while during the second year this cover of sand was not present and consequently the natural surface of these soils was exposed to the atmosphere.

The remarkable equality of temperature, therfore, of the various types of soil during the first and third year when their surface was covered with a thin layer of sand and its inequality during the second year when their surface was not covered suggest the noteworthy fact that it is the thin layer of sand that caused the equality. It accomplished this mainly by equalizing to a greater or less extent the amount of water that the various soils lost through evaporation. The clay, loam, and peat and especially the latter, for instance, possessing a high water content tended to lose more water through evaporation than the sand and gravel whose water content is low, and consequently their temperature was kept lower, just as the results of the second year show. By placing a thin layer of sand, which acted as a mulch, over these types of soil whose water content is high, the evaporation of their moisture was reduced, and their temperature was thereby raised to the same magnitude as that of the soils with a low water content. It was the inequality in the amount of evaporation, therefore, that caused the various types of soil to have different degrees of temperature; and when this difference in evaporation was prevented, then all the diverse classes of soil were equally warm during the spring and summer months.

The knowledge, therefore, that a thin layer of sand at the surface is capable of raising several degrees the temperature of clay and loam and especially of peat, is of the greatest practical importance.

It has already been stated that up to the end of the third year the temperature of the different types of soil was measured at 6, 12, and 18-inch depths. With the beginning of the fourth year, December 1, 1914 to November 30, 1915, the thermometers were removed and placed at the depths of 2, 4, and 6 inches. This change was made with the desire to obtain information on the soil temperature more close to the surface, and also to ascertain whether the general trend of order of the magnitude of temperature at the upper depths would be similar to that at the lower depths. The cover of sand was also removed from the top of these soils so that their natural surface was exposed to the atmosphere during this year. The data obtained during the fourth year are contained in Tables 25 to 36 inclusive.

An examination of these tables shows that (1) all the different types of soil began to freeze almost simultaneously at the respective depths with peat at a slightly slower rate. By the end of December they had all frozen practically down to the 6-inch depth. From this period on they remained at the freezing point throughout the winter until in the spring when they commenced to thaw. During the winter months their temperature was not only almost exactly the same at any corresponding depth but also of practically equal magnitude at all depths. In other words the upper 6-inch layer of soil had the same magnitude of temperature. The lowest average temperature was reached on January 30. At this date the average temperature of the sand went down a few degrees lower than that of the other soils.

(2) Thawing began to occur by March 12 but it did not actually commence until April 1. The gravel, sand, loam, and clay thawed almost simultaneously, with peat about four days later. The temperature of the mineral soils rose quite rapidly to about the same degree, followed by peat with a few days later.

(3) The average temperature of all the soils then tended to be equal, as it ascended, but it did not reach equality until about September. Up to this time the magnitude varied in the different types, being greatest in sand and gravel, followed by clay, loam, and peat, respectively. The temperature of peat, however, was only about 2°F lower than that of the sand or gravel at any corresponding depth, throughout the months of May, June, July, and August.

(4) By the beginning of September this variation in average temperature in the different soils began to disappear and the magnitude became practically identical in all of them at all three depths, and continued to be equal until November 30, which is the end of the year.

The results of the fourth year, show, therefore, that the average temperature of the upper depths of the various types of soil behaved almost in the same manner as that of the lower depths of the second year or corresponding year, when the surface of the soils was not covered with the sand.

THE DAILY REVERSION OF TEMPERATURE AND THE TEMPERATURE GRADIENT AT THE ADJACENT DEPTHS.

Unless the soil is frozen it almost always has a gradient of temperature at its adjacent depths. This gradient of temperature, however reverses itself between day and night during the warm part of the year to the depth that the diurnal-nocturnal amplitude of oscillation of temperature extends. During the day it decreases from the surface downward and during the night the reverse is true. There are periods, however, both in the night and day, when this gradient is not regular. This occurs usually at the time that the reversion takes place. The magnitude of the gradient between the different depths varies with the time, both at day and night, and the air temperaure.

This gradient of soil temperature at the adjacent depths and its reversion between day and night is due, of course, to the fact that the air temperature reverses itself during these periods and the soil receives or loses its heat more at the surface, at any given time, than at the increasing depths.

The soil, down to the depth that the diurnal-nocturnal amplitude of oscillation of temperature extends, receives its temperature in the form of waves. Thus, for instance, in the morning before sunrise, there occurs at its surface a minimum temperature. At this time the temperature is lowest at the surface and increases with depth. As soon as the air temperature begins to rise, however, the temperature at the surface of the soil also commences to climb. The minimum temperature, however, is travelling downward as a wave, and lowers the temperature of the various depths as it reaches them. But as soon as the temperature begins to rise at the surface, it also is conducted downward as a wave and immediately follows the minimum temperature wave, and causes a rise in temperature. At about this point a reversion takes place at and near the surface and the gradient becomes discontinuous. The soil then at the upper and lower depths has a higher temperature than at the intermediate.

The intensity of the minimum wave becomes less and less as it travels downward until finally it reaches a depth where its influence is no longer perceptible. The warm wave, which immediately follows it causes then the temperature of all the depths to rise. A gradient then is again established and decreases in magnitude from the surface downward. The magnitude of this gradient between the adjacent depths increases, as the temperature rises in all depths, until the maximum temperature is attained at the surface when it becomes greatest. At this time the surface soil possesses a very high temperature and the temperature falls very rapidly with the increase in depth.

The maximum temperature which occurred at the surface travels to the lower depths as a maximum wave, and imparts to the different depths a maximum temperature at different times.

But this maximum wave is immediately followed by a cold wave which lowers the temperature at the various depths and decreases the magnitude of the gradient. The cold waves of different intensities continue to travel through the soil, and to cause a reversion of its temperature in the same manner as the warm waves already discussed.

A concrete illustration of the propogation of these cold and warm waves into the soil and the degree of temperature gradient at the adjacent depths at any particular time, are afforded by tables 37 and 38, which contain the temperature of the different types of soil at four different depths taken every 20 minutes from the time that the minimum or maximum temperature occurred at the surface to the time they had reached the lowest depth in all the soils. These records are a few of a great number that were taken at various times throughout the four years. The data presented here were obtaind during the fourth year when the thermometers were placed at 2, 4, and 6 inches from the top. The temperature at 0 inch depth or at the surface was taken by a mercury thermometer which had a very small bulb. This bulb was inserted into the surface soil until it was completely covered. It registered the temperature only of the upper ¼-inch depth.

TABLE 37.—THE DAILY REVERSION OF TEMPERATURE AND THE TEMPERATURE GRADIENT AT THE ADJACENT DEPTHS.

October 22, 1915.		P. M. 12:40	1:00	1:20	1:40	2:00	2:20	2:40	3:00	3:20	3:40	4:00	4:20	4:40	5:00	5:20	5:40	6:00	6:20	6:40	7:00	7:20	7:40
Gravel..............	0″	70.0	69.7	69.0	68.3	67.7	66.9	65.4	64.1	62.0	60.8	58.5	56.0	54.0	52.6	51.2	50.4	49.8	49.2	48.5	48.0	47.6	47.0
	2″	62.2	62.5	62.8	63.0	62.9	62.8	62.5	62.0	61.5	60.8	59.9	58.8	57.7	56.6	55.4	54.5	53.7	53.1	52.5	51.9	51.3	50.8
	4″	57.6	58.1	58.5	59.0	59.3	59.5	59.7	59.8	59.6	59.3	58.9	58.5	57.9	57.4	56.6	55.9	55.3	54.6	54.1	53.7	53.2	52.9
	6″	53.7	54.1	54.8	55.3	55.7	56.1	56.5	56.8	57.0	57.0	57.1	57.1	57.0	56.8	56.5	56.2	55.7	55.3	55.1	54.8	54.3	54.0
Sand...............	0″	69.6	69.0	68.8	68.0	67.1	66.2	65.0	63.8	61.8	60.5	58.3	55.9	53.9	52.2	51.0	50.0	49.3	48.6	47.9	47.4	46.6	45.8
	2″	63.4	63.8	64.2	64.3	64.2	64.1	63.8	63.3	62.6	62.0	60.9	59.7	58.4	57.2	56.0	54.8	53.9	53.3	52.6	51.8	51.3	50.7
	4″	59.5	60.1	60.8	61.3	61.5	61.7	61.7	61.7	61.4	60.9	60.5	59.8	58.9	58.1	57.2	56.4	55.5	54.8	54.2	53.7	53.0	52.5
	6″	55.0	55.7	56.5	57.0	57.5	58.0	58.4	58.5	58.7	58.9	58.8	58.5	58.3	57.0	57.6	57.1	56.8	56.3	55.8	55.3	54.8	54.3
Loam...............	0″	69.7	69.3	68.9	68.0	67.4	66.4	65.0	63.5	61.7	60.0	57.4	55.0	53.0	51.7	50.3	49.7	49.0	48.4	47.6	47.2	46.6	46.0
	2″	59.0	59.6	60.0	60.5	60.7	60.8	60.8	60.6	60.0	59.8	59.1	58.4	57.5	56.6	55.7	54.9	54.1	53.5	53.0	52.5	51.9	51.5
	4″	53.3	53.9	54.5	55.0	55.5	56.0	56.4	56.6	56.8	56.8	56.8	56.8	56.7	56.4	56.0	55.7	55.3	55.0	54.6	54.3	53.9	53.6
	6″	50.1	50.5	50.8	51.2	51.6	52.0	52.4	52.8	53.0	53.1	53.4	53.6	53.7	53.9	53.9	53.8	53.8	53.7	53.6	53.5	53.4	53.3
Clay...............	0″	66.0	65.9	65.7	65.0	64.4	63.6	62.4	61.2	59.7	58.2	56.3	54.0	52.0	50.9	49.7	48.9	48.5	47.9	47.0	46.7	46.1	45.6
	2″	57.5	58.0	58.5	58.8	59.0	59.0	59.0	58.7	58.4	58.1	57.5	57.0	56.1	55.3	54.4	53.8	53.2	52.7	52.1	51.7	51.2	50.8
	4″	52.9	53.4	53.9	54.3	54.8	55.2	55.4	55.7	55.8	55.8	55.8	55.7	55.5	55.2	54.9	54.5	54.0	53.8	53.5	53.2	53.0	52.6
	6″	50.6	51.0	51.4	51.8	52.1	52.5	52.9	53.0	53.4	53.6	53.7	53.9	53.9	54.0	53.9	53.9	53.9	53.7	53.7	53.5	53.4	53.2
Peat...............	0″	67.8	67.7	66.7	65.3	64.9	64.0	62.8	61.6	60.0	58.4	56.0	53.4	51.3	49.4	48.0	47.0	46.8	46.0	45.3	45.0	44.8	43.9
	2″	55.4	56.1	56.9	57.2	57.5	57.8	57.8	57.8	57.6	57.4	57.0	56.5	55.8	55.0	54.4	53.7	53.0	52.5	52.0	51.5	51.0	50.6
	4″	49.0	49.6	50.0	50.6	51.0	51.4	51.8	52.1	52.6	52.7	52.9	53.1	53.2	53.2	53.2	53.2	53.2	53.0	52.9	52.8	52.6	52.4
	6″	49.7	49.9	50.0	50.1	50.3	50.5	50.6	50.8	51.0	51.1	51.3	51.5	51.6	51.8	51.9	52.1	52.1	52.3	52.4	52.5	52.5	52.5

TABLE 37.—*Continued.*

October 23, 1915.		A. M. 5:20	5:40	6:00	6:20	6:40	7:00	7:20	7:40	8:00	8:20	8:40	9:00	9:20	9:40	10:00	10:20	10:40	11:00	11:20
Gravel..................................	0″	38.4	38.3	38.0	38.1	39.0	40.6	42.5	44.2	46.0	47.2	48.8	51.0	50.7	51.9	53.7	55.4	59.0	61.5	62.9
	2″	43.1	42.8	42.5	42.3	42.3	42.3	42.8	43.5	44.3	45.1	45.7	46.7	47.5	48.3	49.1	50.0	51.1	52.7	54.2
	4″	45.4	45.2	45.1	45.0	44.8	44.7	44.6	44.8	45.1	45.4	45.8	46.2	46.9	47.4	47.9	48.3	49.3	49.9	51.0
	6″	48.5	48.4	48.3	48.2	47.7	47.1	46.9	46.7	46.6	46.7	46.9	47.0	47.2	47.5	47.7	47.9	48.3	48.7	49.2
Sand..................................	0″	37.0	36.8	36.3	36.5	36.9	38.8	41.0	43.0	45.0	46.2	47.9	50.0	49.8	50.8	52.4	54.3	57.6	60.2	61.7
	2″	41.5	41.2	40.9	40.7	40.5	40.6	41.0	41.9	42.9	43.9	44.8	45.8	46.9	47.8	48.4	49.6	50.8	52.6	54.3
	4″	43.9	43.7	43.3	43.1	42.9	42.7	42.7	43.0	43.3	44.2	44.7	45.3	46.1	46.7	47.4	48.0	49.1	50.0	51.3
	6″	46.8	46.4	46.3	46.0	45.6	45.5	45.4	45.3	45.3	45.4	45.5	45.9	46.3	46.6	46.9	47.4	48.3	48.4	49.3
Loam..................................	0″	37.8	37.6	37.2	37.3	38.0	39.8	42.6	44.6	46.0	47.0	48.4	50.8	50.0	51.2	53.6	55.0	58.7	60.9	62.6
	2″	44.2	43.6	43.4	43.4	42.9	42.8	42.9	43.3	43.8	44.5	44.9	45.5	46.2	46.9	47.5	48.2	48.5	50.1	51.5
	4″	47.4	47.2	47.1	46.8	46.7	46.5	46.1	46.1	46.1	46.1	46.3	46.4	46.5	46.9	47.3	47.4	47.9	48.2	48.4
	6″	48.8	48.6	48.4	48.3	48.2	48.1	47.6	47.5	47.5	47.5	47.5	47.5	47.5	47.5	47.4	47.5	47.5	47.7	48.0
Clay..................................	0″	37.6	37.4	37.0	37.0	38.0	38.8	41.0	43.0	44.9	45.7	47.0	49.0	48.6	49.8	51.4	52.9	56.0	58.0	59.2
	2″	44.4	43.8	43.6	43.4	43.1	43.0	43.0	43.5	43.9	44.4	45.0	45.4	46.2	46.8	47.4	48.0	48.5	49.6	51.0
	4″	47.0	46.6	46.4	46.1	46.0	45.8	45.3	45.3	45.3	45.4	45.8	45.9	46.3	46.5	46.8	47.3	47.5	47.9	48.4
	6″	48.7	48.6	48.5	48.4	48.4	48.0	48.0	47.7	47.5	47.4	47.4	47.4	47.4	47.5	47.5	47.8	47.9	47.9	48.4
Peat..................................	0″	34.3	34.2	33.0	33.0	33.6	35.5	38.6	41.0	43.9	45.0	47.0	49.3	49.6	50.8	52.9	54.6	59.0	61.6	63.8
	2″	45.4	42.6	42.4	42.2	41.8	41.6	41.5	41.7	42.0	42.5	43.0	43.6	44.4	45.1	45.7	46.4	47.1	47.5	49.0
	4″	47.5	47.2	47.0	46.9	46.8	46.5	46.3	46.2	45.5	45.5	45.7	45.7	45.8	45.8	45.8	46.0	46.2	46.5	46.7
	6″	50.9	50.7	50.5	50.5	50.4	50.4	50.3	50.2	50.0	49.8	49.7	49.6	49.6	49.5	49.4	49.2	49.2	49.2	49.2

TABLE 38.—THE DAILY REVERSION OF TEMPERATURE AND THE TEMPERATURE GRADIENT AT THE ADJACENT DEPTHS.

July 9, 1915.		P. M. 1:00	1:30	1:50	2:10	2:30	2:50	3:10	3:30	3:50	4:10	4:30	4:50	5:10	5:30	5:50	6:10	6:30	6:50	7:10	7:30	7:50	8:10	8:30	8:50	9:10	9:30	9:50
Gravel..	0″	102.0	101.6	101.7	99.0	99.8	100.2	98.3	96.0	93.3	90.0	87.7	86.1	83.5	82.2	81.8	78.9	77.0	75.0	73.4	71.9	70.9	70.0	69.4	69.0	68.4	68.0	67.3
	2″	92.1	92.9	93.3	93.5	93.2	93.2	93.1	93.1	91.8	90.7	89.1	87.8	86.4	85.2	84.0	82.1	81.5	80.3	78.9	77.5	76.7	75.8	74.9	74.0	73.4	72.6	72.0
	4″	83.9	84.7	85.4	86.0	86.4	86.6	86.9	87.0	86.9	86.4	86.0	85.3	84.5	83.9	83.0	82.3	81.3	80.4	79.5	78.4	77.8	77.0	76.3	75.5	74.8	74.1	73.6
	6″	76.1	77.0	77.7	78.3	79.1	79.6	80.1	80.5	80.8	81.0	81.1	81.0	80.9	80.6	80.4	80.2	79.6	79.1	78.7	77.9	77.6	77.0	76.5	76.0	75.5	74.9	74.5
Sand....	0″	105.0	104.4	104.0	101.4	101.1	101.3	99.9	97.6	94.7	91.2	88.9	87.2	84.6	83.4	81.9	79.6	77.4	75.4	73.7	71.9	70.8	70.0	69.0	68.6	68.0	67.4	66.7
	2″	94.5	94.8	95.2	95.4	94.9	94.8	94.7	94.3	93.3	92.1	90.8	89.4	87.5	86.7	85.5	84.2	83.8	81.5	80.2	78.6	77.8	76.8	75.8	74.8	74.1	73.4	72.6
	4″	88.1	88.8	89.3	89.9	90.1	90.1	90.2	90.3	89.8	89.4	88.6	87.7	86.4	85.8	84.9	83.9	82.9	82.0	80.8	79.6	78.9	78.0	77.2	76.4	75.5	74.9	74.1
	6″	80.5	81.3	82.1	82.8	83.4	83.9	84.3	84.5	84.8	85.0	84.8	84.6	84.1	83.8	83.4	82.8	82.2	81.6	80.8	80.2	79.6	78.9	78.2	77.6	76.9	76.3	75.8
Loam...	0″	100.7	100.0	100.2	97.9	98.3	98.7	97.2	95.0	92.0	88.9	86.4	85.0	82.4	81.3	79.9	78.0	76.1	74.4	72.8	71.0	70.1	69.8	68.8	68.3	67.8	67.2	66.8
	2″	83.8	84.6	85.5	85.3	86.0	86.1	85.5	85.9	84.4	84.9	84.1	83.1	82.1	81.3	80.5	79.6	78.6	77.8	76.6	75.4	74.7	73.9	73.1	72.3	71.7	71.1	70.5
	4″	75.8	76.6	77.4	78.0	78.6	79.0	79.5	80.0	80.3	80.4	80.4	80.4	80.0	80.0	79.5	79.1	78.8	78.3	77.8	77.1	76.9	76.4	75.8	75.4	74.9	74.5	74.0
	6″	68.0	68.7	69.4	69.9	70.5	71.0	71.4	71.8	72.4	72.9	73.2	73.5	73.7	73.9	73.9	74.0	74.1	74.0	73.8	73.7	73.6	73.5	73.2	73.0	72.8	72.4	72.2
Clay....	0″	97.2	96.9	97.0	94.9	95.0	95.0	93.6	91.4	88.9	85.9	83.9	82.4	80.0	79.0	78.2	76.0	74.4	72.9	71.2	69.9	69.3	68.3	67.7	67.2	67.0	66.5	66.0
	2″	82.9	83.6	84.1	84.5	84.5	84.5	84.6	84.5	84.1	83.5	82.8	81.9	80.8	80.4	79.5	78.7	77.9	77.0	76.1	74.8	74.5	73.8	73.0	72.3	71.7	71.3	70.8
	4″	73.3	73.8	74.5	75.3	75.8	75.9	76.0	76.1	76.3	76.6	76.9	76.8	76.6	76.3	75.8	75.5	74.9	74.6	74.0	73.7	73.4	72.9	72.2	71.6	71.4	70.9	70.5
	6″	68.8	69.4	70.0	70.5	71.1	71.7	72.0	72.5	72.9	73.4	73.6	73.9	73.9	74.1	74.0	74.0	73.9	73.8	73.6	73.4	73.3	73.1	72.8	72.5	72.3	72.0	71.8
Peat....	0″	97.9	97.4	97.3	95.0	95.4	94.9	92.9	90.9	88.1	85.2	83.1	82.0	79.5	78.4	76.9	75.2	73.2	71.4	69.6	67.8	66.9	66.0	65.3	65.3	64.9	64.5	63.9
	2″	81.4	82.1	83.0	83.5	83.8	84.0	84.2	84.3	84.0	83.5	82.9	82.1	81.1	80.5	79.9	79.0	78.2	77.4	76.4	75.4	74.7	74.1	73.3	72.5	71.8	71.3	70.8
	4″	69.4	70.0	70.8	71.2	71.9	72.5	73.0	73.6	73.9	74.2	74.5	74.7	74.8	74.8	74.9	74.7	74.6	74.5	74.1	73.9	73.7	73.5	73.1	72.8	72.4	72.0	71.8
	6″	64.8	65.0	65.4	66.8	66.2	66.4	66.7	67.0	67.3	67.8	68.1	68.4	68.7	68.9	69.1	69.3	69.6	69.8	69.9	70.0	70.0	70.0	70.1	70.1	70.1	70.1	70.0

TABLE 38.—*Continued.*

July 10, 1915.		A. M. 3:20	3:40	4:00	4:20	4:40	5:00	5:20	5:40	6:00	6:20	6:40	7:00	7:20	7:40	8:00	8:20	8:40	9:00	9:20	9:40	10:00	10:20	10:40
Gravel........	0″	59.0	59.1	59.0	59.0	59.7	60.0	61.6	63.8	66.5	67.8	71.7	73.8	76.3	78.4	80.3	82.8	84.8	86.0	87.4	89.4	92.9	95.0	95.4
	2″	64.3	64.0	63.6	63.4	63.2	63.1	63.1	63.5	64.1	65.1	66.4	67.8	69.4	70.8	72.4	74.0	75.6	77.6	79.1	80.9	82.8	84.5	86.1
	4″	66.7	66.2	65.8	65.5	65.3	65.0	64.9	64.9	64.9	65.1	65.7	66.3	67.0	68.0	68.9	69.9	71.1	72.4	73.7	74.9	76.4	77.7	79.0
	6″	68.5	68.2	67.9	67.5	67.2	67.0	66.7	66.5	66.4	66.3	66.2	66.4	66.6	66.9	67.4	67.8	68.5	69.2	69.9	70.6	71.4	72.4	73.4
Sand.........	0″	58.0	58.0	57.9	57.9	58.5	59.0	60.5	62.6	65.2	67.8	70.9	73.9	76.8	79.5	81.6	85.0	87.6	90.4	92.9	94.0	96.9	99.0	99.0
	2″	64.1	63.6	63.2	63.0	62.7	62.6	62.6	63.0	63.8	64.8	66.2	67.7	69.5	71.0	72.9	74.9	76.7	78.8	80.4	82.1	83.8	85.4	87.0
	4″	66.0	65.6	65.1	64.7	64.4	64.2	64.1	64.1	64.3	64.7	65.4	66.2	67.3	68.4	69.6	71.0	72.5	74.0	75.4	76.9	78.3	79.9	81.1
	6″	68.5	68.1	67.6	67.2	66.9	66.7	66.4	66.1	66.0	66.0	66.1	66.3	66.7	67.1	67.7	68.6	69.3	70.3	71.1	72.0	73.3	74.2	75.3
Loam.........	0″	58.9	58.9	58.9	58.9	59.6	59.9	60.8	63.1	66.0	68.0	70.6	72.9	75.6	78.0	80.0	83.0	85.1	87.7	89.8	90.4	93.2	95.0	95.0
	2″	63.6	63.1	62.9	62.5	62.3	62.1	62.0	62.1	62.3	62.8	63.4	64.2	65.3	66.2	67.4	69.0	70.5	72.0	73.6	74.8	76.2	77.8	79.2
	4″	68.3	68.0	67.6	67.2	67.0	66.8	66.6	66.4	66.2	66.0	66.1	66.2	66.4	66.7	67.0	67.6	68.1	68.8	69.6	70.1	71.1	71.7	72.8
	6″	68.5	68.2	68.0	67.6	67.5	67.3	67.0	66.8	66.5	66.5	66.3	66.1	66.1	66.0	66.1	66.1	66.3	66.4	66.7	66.9	67.2	67.5	68.0
Clay.........	0″	58.2	58.3	58.3	58.3	59.0	59.3	60.4	62.0	64.6	66.4	68.8	71.0	73.0	75.3	77.3	80.0	82.2	85.0	87.0	88.3	90.8	92.6	92.7
	2″	64.6	64.1	63.9	63.7	63.5	63.3	63.3	63.3	63.5	64.0	64.6	65.4	66.2	67.0	68.0	69.2	70.3	71.6	72.9	74.1	75.5	76.9	78.2
	4″	66.5	66.3	66.0	65.7	65.3	65.2	65.0	64.9	64.8	64.8	65.0	65.1	65.4	65.6	66.0	66.6	66.9	67.7	68.0	68.8	69.6	70.6	71.3
	6″	68.0	67.7	67.5	67.3	67.1	66.8	66.7	66.6	66.3	66.1	66.0	66.0	66.0	66.0	66.0	66.0	66.3	66.5	66.8	67.0	67.4	67.9	68.4
Peat..........	0″	55.3	55.8	55.5	55.8	56.9	57.7	59.9	62.4	65.7	68.2	71.0	73.6	75.8	77.3	78.4	80.9	83.0	85.6	87.8	89.0	91.3	93.2	93.3
	2″	64.2	63.8	63.6	63.1	62.9	62.7	62.6	62.6	63.0	63.3	64.0	64.7	65.6	66.5	67.4	68.6	69.6	70.9	72.1	73.5	74.9	76.4	77.9
	4″	67.4	67.1	66.9	66.7	66.5	66.2	66.0	65.8	65.6	65.4	65.3	65.3	65.3	65.3	65.4	65.6	65.8	66.2	66.5	66.9	67.4	67.8	68.4
	6″	63.6	68.4	68.3	68.1	68.0	67.9	67.8	67.6	67.5	67.3	67.2	67.0	67.0	66.9	66.8	66.8	66.7	66.7	66.7	66.7	66.7	66.8	66.9

The above figures, therefore, show that the heat is propogated into the soil in the form already described.

They also show that the degree of gradient of temperature is much greater during the day when the maximum temperature is reached than during the night when the minimum is attained, at the surface. Thus, for instance in the former case the difference is almost as high as 30°F, while in the latter case it is only about 10°F. It is to be noted that in both instances the amplitude is greatest between the surface and 2-inch depth and decreases rapidly with the succeeding depths.

Another extremely interesting fact that is revealed by the above tables is that the rate at which the maximum and minimum waves travel at the various depths of any particular soil tends to follow approximately a mathematical law. This law may be stated as follows: the lag of the maximum and minimum epochs tends to be approximately proportional to the depth, in all the different types of soil.

The larger gradient during the day over that at night is due, of course, to the fact that during the insolation the soil receives its heat both by absorption and by contact with the warm air and since it is a poor conductor of heat the temperature rises at the top much faster than it is conducted downward. While during the night it is this high temperature at the depths that is being lost, through radiation and contact with the cold air, and since the rate of cooling is slower than that of warming, the various adjacent depths do not attain very large gradients of temperature.

The night or early morning gradient at the various adjacent depths is greatest in the fall, and slightly smaller in the summer, and spring. In the fall the magnitude between the surface and 6-inch depth is usually about 5°F while in the summer and fall it is about 3°F, in the mineral soil, and slightly higher in the peat.

The degree of gradient at the various depths both at night and day is of great importance from the standpoint of aeration and thermal movement of moisture in soils as shown by the author elsewhere[4].

EFFECT OF METEOROLOGICAL ELEMENTS ON THE SOIL TEMPERATURE.

It has already been stated that the external factors which comprise the meteorological elements act upon the intrinsic factors and cause the temperature of the soil to vary as they themselves vary. These meteorological elements, however, do not all influence the soil temperature in the same direction, and are very complex as to their behavior and consequently the influence of all of them is not readily apparent. In the previous report an attempt was made to establish a connection between the soil temperature and the various chief meteorlogical elements but it was not altogether successful. The only factors with which the soil temperature correlated very closely was the air temperature, the dew point and the sunshine during the summer.

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[4] Technical Bul. 22 Mich. Expt. Sta., 1915.

THE DAILY AND MONTHLY MAXIMUM AND MINIMUM TEMPERATURE AND THE MONTHLY AMPLITUDE.

Thus far the average daily march of average temperature of the various types of soil has been considered. It will now be of interest to examine the daily maximum and minimum temperature and consequently also the amplitude of these same classes of soil. The data for the three years are included in Tables 39 to 74 inclusive. As previously stated these maximum and minimum temperatures do not represent the absolute values, but they approach these actual or true values very closely.

BEGINNING WITH SECOND YEAR.

TABLE 39.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, DECEMBER, 1912.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
2	**Max**...	43.7	42.7	41.9	44.0	42.6	42.5	40.9	40.2	40.6	42.2	40.6	40.7	38.6	37.8	40.7
	Min....	42.0	41.2	40.3	41.7	41.3	40.7	39.1	38.3	39.8	40.7	38.8	39.4	36.4	37.5	40.6
3	**Max**....	37.7	39.4	41.5	37.5	39.6	41.8	38.3	40.3	41.4	38.4	40.6	41.5	38.2	38.6	40.9
	Min....	36.8	38.3	40.7	36.5	38.3	41.4	37.0	39.6	41.3	37.1	39.6	41.2	37.3	38.4	40.8
4	**Max**....	39.0	39.0	39.9	38.9	39.1	40.1	37.5	38.9	40.9	38.1	39.0	40.2	36.5	38.4	40.7
	Min....	37.1	38.1	39.6	36.8	38.1	39.9	36.8	38.5	40.0	37.1	38.5	39.7	36.4	38.1	40.6
5	**Max**....	40.4	39.7	39.9	40.6	39.7	40.4	38.1	38.8	40.5	38.9	38.9	39.9	36.7	38.1	40.5
	Min....	36.4	37.9	39.7	35.9	37.9	39.9	36.4	38.5	40.3	36.6	38.5	39.8	36.3	37.8	40.3
6	**Max**....	43.2	42.9	42.3	43.1	43.1	42.5	41.9	41.1	41.4	42.7	41.2	41.3	39.7	39.1	41.0
	Min....	38.2	39.9	41.7	38.2	40.0	41.9	33.9	40.7	41.1	39.0	41.0	41.1	39.1	38.4	40.9
7	**Max**....	36.1	38.1	40.8	36.9	38.2	41.0	37.1	39.9	41.5	37.1	39.8	41.2	38.0	39.1	41.2
	Min....	35.1	37.0	39.7	35.0	37.2	40.1	36.1	39.1	41.0	36.0	39.0	40.5	37.2	38.5	40.4
9	**Max**....	33.1	35.1	38.2	34.2	35.6	38.8	34.2	37.4	39.7	34.0	37.2	38.9	35.5	38.2	40.9
	Min....	32.9	34.7	38.0	33.1	35.0	38.2	33.9	37.1	39.5	33.7	36.6	38.5	35.0	37.8	40.6
10	**Max**....	32.5	34.4	37.2	32.8	34.8	37.9	33.6	36.5	38.9	33.2	36.3	38.2	34.7	37.4	40.3
	Min....	31.7	33.7	36.9	32.3	34.1	37.4	33.1	36.4	38.7	32.9	36.1	37.8	34.4	37.1	39.3
11	**Max**....	33.0	34.7	37.5	33.0	34.9	37.7	33.4	36.3	38.5	33.2	36.1	37.8	34.3	37.2	40.1
	Min....	32.1	33.7	36.6	32.1	34.3	37.3	32.9	35.8	38.1	32.7	35.5	37.3	33.6	36.4	39.3
12	**Max**....	31.1	33.1	36.4	31.3	33.8	37.2	32.7	35.8	38.0	32.5	35.5	37.3	33.7	36.3	39.1
	Min....	30.2	32.6	35.7	30.3	33.0	36.4	32.2	35.2	37.6	31.7	34.9	36.7	33.0	36.0	38.6
13	**Max**....	30.2	32.2	35.7	30.3	32.9	36.3	31.7	35.0	37.5	31.6	34.8	36.5	32.9	35.6	38.7
	Min....	29.7	31.7	35.0	29.7	32.2	35.8	31.3	34.5	36.9	31.0	34.1	36.0	32.4	35.1	38.2
14	**Max**....	30.9	31.9	35.3	30.7	32.7	35.9	31.3	34.6	37.0	31.4	34.2	36.1	32.7	35.2	38.2
	Min....	29.0	31.7	33.9	28.8	31.2	34.9	30.3	33.2	35.9	30.2	33.0	34.9	31.4	34.1	37.5
16	**Max**....	31.0	32.1	34.8	31.2	32.9	35.6	31.3	33.9	36.2	31.2	33.8	35.4	32.3	34.7	37.3
	Min....	30.9	31.9	34.7	31.0	32.8	35.4	31.2	33.8	36.2	31.1	33.6	35.3	32.0	34.4	37.2
17	**Max**....	31.4	32.6	35.0	32.7	33.4	35.8	31.6	34.2	36.4	31.7	34.0	35.6	32.4	34.6	37.3
	Min....	31.1	32.3	34.7	31.4	33.0	35.4	31.2	33.7	36.2	31.2	33.6	35.1	31.9	34.2	37.1
18	**Max**....	32.4	33.6	35.8	33.4	34.6	36.6	32.2	34.8	36.8	32.4	34.6	36.1	32.8	34.9	37.7
	Min....	32.3	33.3	35.7	33.2	34.3	36.4	32.0	34.5	36.6	32.2	34.4	35.7	32.8	34.8	37.5
19	**Max**....	32.9	34.0	36.0	33.2	34.8	36.8	32.3	34.9	36.9	32.7	34.9	36.4	32.9	34.9	37.7
	Min....	32.4	33.5	35.7	33.1	34.6	36.5	32.2	34.7	36.6	32.5	34.8	36.1	32.8	34.8	37.4
20	**Max**....	33.1	34.3	36.0	33.2	34.7	36.8	32.5	35.0	36.9	32.8	34.9	36.4	33.0	34.9	37.6
	Min....	32.7	33.9	35.8	32.9	34.2	36.4	32.1	34.4	36.5	32.4	34.5	35.8	32.7	34.5	37.2
21	**Max**....	33.0	34.0	35.9	33.0	34.6	36.4	32.4	34.8	36.6	32.8	34.9	36.0	32.9	34.8	37.4
	Min....	33.0	34.0	35.8	32.9	34.4	36.4	32.3	34.7	36.4	32.7	34.8	35.9	32.8	34.7	37.2
23	**Max**....	32.7	33.8	35.8	32.0	33.7	36.3	32.0	34.6	36.1	32.5	34.7	35.8	32.4	34.3	36.9
	Min....	31.4	32.3	34.9	31.4	33.1	35.5	31.4	33.8	35.7	31.8	34.0	35.2	31.9	33.8	36.4
24	**Max**....	31.5	32.9	34.9	31.3	33.0	35.2	31.2	33.7	35.8	31.4	33.7	35.0	31.6	33.8	36.3
	Min....	31.3	32.5	34.5	31.1	32.7	35.0	31.0	33.3	35.4	31.3	33.4	35.0	31.4	33.4	36.0
26	**Max**....	31.9	33.2	35.2	31.8	33.1	35.7	31.6	34.2	35.9	31.9	34.1	35.5	32.2	34.1	36.6
	Min....	31.6	32.9	34.9	31.2	32.8	35.2	31.2	33.7	35.7	31.4	33.7	35.0	31.9	33.8	36.4
27	**Max**....	32.6	33.7	35.5	32.3	33.8	35.9	32.1	34.4	36.3	32.5	34.4	35.8	32.7	34.5	37.0
	Min....	32.2	33.2	35.1	31.7	33.2	35.7	31.8	34.1	36.0	32.1	34.2	35.6	32.1	34.1	36.8
28	**Max**....	32.2	33.5	35.5	31.9	33.4	35.8	32.0	34.3	36.2	32.4	34.3	35.8	32.5	34.3	36.9
	Min....	31.0	32.3	34.6	31.0	32.7	34.9	31.1	33.4	35.1	31.2	33.6	35.0	31.7	33.5	36.2
30	**Max**....	32.1	33.2	35.1	32.6	33.2	35.3	31.7	33.9	35.7	32.1	34.1	35.1	32.0	33.8	36.3
	Min....	31.6	32.9	34.9	31.6	32.9	35.1	31.2	33.4	35.3	31.4	33.6	35.0	31.7	33.3	36.2
31	**Max**....	31.9	33.0	34.8	31.9	33.2	35.1	31.4	33.7	35.6	31.9	33.8	35.1	31.9	33.7	36.3
	Min....	31.7	32.9	34.7	31.6	32.9	35.0	31.2	33.4	35.2	31.7	33.4	34.8	31.4	33.3	35.9
Ave.	**Max**..	**33.98**	**35.08**	**37.08**	**34.15**	**35.42**	**37.58**	**33.80**	**36.05**	**37.89**	**34.06**	**36.02**	**37.34**	**34.12**	**35.93**	**38.54**
	Min..	**32.98**	**34.34**	**36.55**	**32.98**	**34.65**	**37.07**	**33.12**	**35.51**	**37.48**	**33.27**	**35.49**	**36.90**	**33.58**	**35.51**	**38.18**
	Range	**1.00**	**0.74**	**0.53**	**1.17**	**0.77**	**0.51**	**0.66**	**0.54**	**0.41**	**0.79**	**0.53**	**0.44**	**0.54**	**0.42**	**0.36**

TABLE 40.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JANUARY, 1913.

Date—Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1 Max....	31.7	32.9	34.3	31.6	32.9	34.9	31.2	33.3	35.0	31.6	33.6	34.9	31.6	33.2	35.9
Min....	31.6	32.6	34.2	31.5	32.8	34.8	31.1	33.1	34.9	31.5	33.2	34.6	31.3	33.1	35.7
2 Max....	31.9	32.9	34.4	31.8	33.1	35.2	31.3	33.6	35.2	31.9	33.7	34.9	31.7	33.4	35.9
Min....	31.7	32.8	34.2	31.6	32.8	34.8	31.0	33.0	34.8	31.3	33.2	34.4	31.3	33.1	35.7
3 Max....	32.7	33.3	35.0	32.4	33.7	35.4	31.7	33.8	35.5	32.4	34.1	35.1	32.0	33.8	36.2
Min....	32.0	33.1	34.9	31.8	33.3	35.3	31.3	33.4	35.2	32.1	33.8	35.0	31.7	33.6	35.9
4 Max....	32.7	33.4	35.0	32.4	33.7	35.4	31.8	33.9	35.6	32.3	34.2	35.2	32.1	33.8	36.1
Min....	32.2	33.2	34.8	32.0	33.4	35.2	31.4	33.7	35.2	32.1	33.8	35.0	31.8	33.4	35.8
6 Max....	31.7	32.8	34.7	31.6	33.0	34.9	31.3	33.3	35.2	31.7	33.6	35.0	31.7	33.5	36.0
Min....	31.3	32.5	34.0	31.3	32.6	34.6	30.9	33.1	35.0	31.3	33.2	34.6	31.1	32.8	35.7
7 Max....	32.7	33.6	35.2	32.6	33.8	35.6	31.8	34.2	35.7	32.5	34.3	35.6	32.3	34.2	36.6
Min....	32.2	33.2	34.9	32.4	33.2	35.2	31.5	33.7	35.5	32.1	33.8	35.1	31.9	33.7	36.3
8 Max....	32.7	33.6	35.1	32.5	33.8	35.7	31.8	34.1	35.8	32.4	34.2	35.1	32.2	34.1	36.5
Min....	32.7	33.6	35.1	32.5	33.8	35.7	31.8	34.1	35.8	32.4	34.2	35.1	32.2	34.1	36.5
9 Max....	31.9	33.2	34.4	31.7	33.0	35.0	31.3	33.4	35.1	31.8	33.3	34.8	31.5	32.8	35.7
Min....	31.7	32.7	34.3	31.6	32.8	34.7	31.1	33.2	34.8	31.4	33.3	34.7	31.5	32.8	35.7
10 Max....	32.2	33.2	34.8	32.2	33.1	35.1	31.7	33.7	35.3	32.1	33.6	34.9	31.9	33.4	35.9
Min....	31.8	32.8	34.2	31.5	32.9	34.7	31.2	33.2	34.8	31.5	33.1	34.4	31.3	33.1	35.7
11 Max....	32.2	33.1	34.5	31.9	33.1	35.0	31.3	33.3	35.0	31.9	33.5	34.7	31.8	33.4	35.7
Min....	32.1	33.0	34.4	31.7	33.0	34.9	31.3	33.3	34.9	31.8	33.3	34.6	31.6	33.1	35.6
13 Max....	32.7	33.7	34.9	32.2	33.7	35.2	31.9	33.9	35.2	32.1	33.9	35.0	32.0	33.7	36.1
Min....	32.3	33.4	34.9	32.1	33.3	35.2	31.4	33.8	35.1	32.1	33.8	34.9	31.8	33.3	35.8
14 Max....	33.0	33.8	35.3	32.4	33.8	35.6	31.9	33.9	35.2	32.3	34.1	35.2	32.5	34.0	36.2
Min....	32.2	33.1	34.6	32.1	33.3	34.9	31.2	33.3	34.9	31.8	33.4	34.8	31.7	33.2	35.4
15 Max....	32.8	33.7	35.1	32.3	33.6	35.1	31.7	33.7	35.2	32.2	33.9	34.9	31.8	33.3	35.8
Min....	32.5	33.2	34.8	32.1	33.4	35.0	31.3	33.5	35.1	31.9	33.8	34.7	31.7	33.2	35.7
16 Max....	32.7	33.6	34.9	32.2	33.0	34.3	31.9	33.8	35.3	32.2	33.9	35.0	31.9	33.7	36.0
Min....	32.6	33.4	34.8	32.0	32.9	34.2	31.7	33.7	35.0	32.0	33.8	34.9	31.8	33.6	35.7
17 Max....	32.4	33.7	35.0	32.1	34.0	34.8	32.0	33.9	35.1	32.3	34.0	34.9	31.9	33.4	35.8
Min....	32.3	33.2	34.8	32.0	33.9	34.7	31.8	33.6	34.9	32.1	33.8	34.8	31.9	33.3	35.7
18 Max....	32.4	33.9	35.0	32.3	33.8	35.1	31.9	33.8	35.3	32.2	34.1	35.1	32.1	33.6	35.8
Min....	32.1	33.7	34.6	32.0	33.5	34.8	31.8	33.4	35.0	32.1	33.9	34.9	31.9	33.1	35.4
20 Max....	33.3	34.4	35.5	33.7	34.4	35.8	32.6	34.2	35.9	33.0	34.4	35.5	32.5	34.0	36.0
Min....	32.5	33.3	34.5	32.4	33.6	35.1	31.7	33.3	34.9	32.3	33.7	35.0	31.8	33.2	35.8
21 Max....	33.8	34.3	35.8	33.3	34.3	35.9	32.6	34.3	35.8	33.0	34.4	35.7	32.3	33.8	36.3
Min.....	33.0	33.9	35.1	33.2	34.1	35.2	32.0	33.9	35.3	32.7	34 1	35.0	31.9	33.2	35 7
22 Max....	33.6	34.3	35.7	33.5	34.6	35.7	32.2	34.2	35.8	33.0	34.3	35.3	32.3	33.7	35.9
Min....	33.0	33.9	34.9	32.9	33.8	35.1	31.7	33.4	35.0	32.4	33.8	34.8	31.7	33.1	35.3
23 Max....	33.3	34.2	35.6	33.2	34.2	35.6	32.1	33.9	35.3	32.8	34.3	35.2	32.1	33.4	35.9
Min....	33.0	34.0	35.2	32.9	34.0	35.3	31.9	33.7	35.1	32.8	34.0	35.1	31.9	33.2	35.4
24 Max....	33.3	34.2	35.6	33.1	34.1	35.5	32.2	34.1	35.4	33.0	34.6	35.4	32.2	33.7	36.1
Min....	33.0	33.8	35.1	32.9	33.9	35.1	31.8	33.7	35.1	32.6	33.9	34.9	31.8	33.2	35.4
25 Max....	33.3	34.2	35.5	33.2	34.1	35.7	32.1	34.1	35.4	33.1	34.4	35.4	32.2	33.6	35.9
Min....	33.2	34.0	35.1	33.0	34.0	35.3	32.0	33.9	35.3	32.7	33.9	35.0	31.9	33.2	35.7
27 Max....	33.3	34.0	35.3	33.0	34.0	35.2	31.9	34.0	35.1	32.9	34.1	35.1	31.9	33.2	35.7
Min....	33.0	33.8	35.0	32.7	33.9	35.1	31.9	33.9	35.0	32.7	33.9	34.9	31.7	33.0	35.3
28 Max....	32.7	33.6	35.1	32.1	33.7	35.1	32.2	34.0	35.3	32.9	34.3	35.4	32.2	33.3	35.9
Min....	32.2	33.2	34.8	31.7	33.1	34.9	31.7	33.5	34.9	32.3	33.8	34.8	31.7	33.0	35.3
29 Max....	31.6	33.2	35.1	30.2	33.0	35.1	31.8	34.0	35.3	32.2	34.1	35.1	31.2	33.3	35.8
Min....	30.9	32.7	34.3	29.1	32.3	34.4	31.2	33.7	35.0	31.8	33.8	34.7	30.8	33.2	35.5
30 Max....	31.2	32.4	34.2	31.1	32.2	34.3	31.2	33.3	34.9	31.4	33.3	34.4	30.9	33.0	35.2
Min....	30.8	32.0	33.9	30.3	32.0	34.1	30.9	33.0	34.7	31.2	33.1	34.1	30.8	32.8	34.9
31 Max....	31.8	32.8	34.0	31.5	32.3	34.1	31.3	33.3	34.9	31.9	33.3	34.4	31.4	33.1	35.3
Min....	31.5	32.3	33.9	31.1	32.0	33.8	31.0	33.1	34.6	31.4	33.0	34.2	31.2	32.8	35.1
Ave. Max..	32.58	33.56	35.00	32.30	33.56	35.19	31.80	33.81	35.33	32.34	33.98	35.08	31.93	33.53	35.93
Min..	32.20	33.20	34.64	31.94	33.24	34.89	31.47	33.49	35.03	32.01	33.64	34.78	31.62	33.20	35.62
Range	0.38	0.36	0.36	0.36	0.32	0.30	0.33	0.32	0.30	0.33	0.34	0.30	0.31	0.33	0.31

TABLE 11.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, FEBRUARY, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	Max....	30.0	32.7	34.2	31.7	32.9	34.3	31.3	33.3	34.9	31.7	33.3	34.6	30.0	33.2	35.3
	Min....	29.1	31.9	34.1	30.0	32.7	34.3	30.8	33.2	34.9	31.0	33.2	34.3	29.4	33.0	35.2
3	Max....	30.0	31.0	33.4	30.0	31.3	33.8	29.8	32.9	34.3	29.8	32.8	33.9	29.6	32.7	35.2
	Min....	27.7	29.9	32.9	26.2	30.7	33.4	28.9	32.2	34.1	29.0	32.2	33.6	27.2	32.2	34.8
4	Max....	28.7	30.3	33.2	27.3	30.8	33.8	29.2	32.8	34.4	29.5	32.7	34.0	28.0	32.8	35.1
	Min....	27.0	30.0	33.1	25.0	30.3	33.5	28.8	32.7	34.2	28.8	32.2	33.7	27.0	32.8	35.0
5	Max....	25.8	28.5	32.8	22.9	28.5	33.2	26.9	32.1	33.9	27.0	31.9	33.2	25.0	32.2	34.8
	Min....	23.3	27.3	32.4	19.9	27.8	33.0	25.8	31.9	33.8	26.1	31.8	33.1	23.1	31.9	34.4
6	Max....	24.7	27.0	32.1	22.2	27.0	33.0	25.8	31.8	33.9	25.8	31.7	33.2	23.3	32.0	34.6
	Min....	22.1	25.6	31.8	18.3	26.0	32.3	23.9	31.2	33.1	24.4	31.1	32.8	21.0	31.4	34.3
7	Max....	26.9	28.1	31.8	25.3	28.8	32.8	26.7	31.4	33.7	26.9	31.1	33.0	25.1	31.8	34.6
	Min....	25.0	27.3	31.7	22.8	27.4	32.7	25.3	31.2	33.3	25.8	30.9	32.7	23.3	31.4	34.3
8	Max....	27.9	28.6	31.3	28.0	29.3	32.2	27.2	31.1	33.3	27.0	30.4	32.8	26.8	31.4	34.2
	Min....	25.8	28.0	31.1	24.0	28.3	32.0	25.9	30.7	32.7	26.1	29.9	31.9	24.4	31.0	33.9
10	Max....	27.7	28.1	31.6	28.1	28.7	32.4	26.8	30.8	33.2	26.9	30.3	32.4	26.3	31.1	34.0
	Min....	24.1	26.2	30.9	21.8	27.0	31.6	24.8	30.1	32.5	25.2	29.8	31.7	22.9	30.2	33.3
11	Max....	28.9	29.7	31.0	29.2	30.0	31.3	28.0	30.0	32.0	28.6	30.0	31.4	28.2	30.4	33.3
	Min....	27.2	28.3	30.2	27.8	28.9	31.1	27.1	29.8	31.5	27.4	29.6	31.0	27.3	29.8	32.8
12	Max....	25.9	27.4	31.0	24.2	28.0	32.0	26.1	30.2	32.8	26.4	30.0	31.8	24.0	30.0	33.7
	Min....	23.3	26.3	30.9	21.0	27.2	31.2	24.9	30.0	31.8	25.3	29.4	31.2	22.2	29.8	33.0
13	Max....	25.0	26.3	30.9	23.3	26.7	31.2	24.8	29.9	32.6	25.0	29.3	31.8	23.0	28.8	33.3
	Min....	21.1	24.2	30.2	17.3	25.1	30.7	22.3	29.2	32.1	23.1	28.7	31.1	19.1	28.0	32.9
14	Max....	27.7	27.8	30.4	28.1	28.2	31.0	26.1	29.2	32.4	26.0	28.8	31.1	25.9	28.1	32.9
	Min....	22.9	25.8	30.1	20.1	26.7	30.7	24.0	28.9	31.9	24.5	28.4	30.9	21.8	27.9	32.3
15	Max....	29.2	29.8	30.9	29.8	30.0	31.2	28.2	29.8	31.7	28.2	29.6	30.9	28.5	29.3	32.8
	Min....	28.9	29.4	30.4	28.6	29.9	30.9	27.7	29.4	31.3	27.4	29.0	30.7	27.7	29.0	32.0
17	Max....	29.9	30.2	31.2	29.9	30.3	31.2	28.8	30.1	31.7	28.9	30.0	31.0	28.9	29.8	32.5
	Min....	29.0	29.9	31.0	28.4	29.9	31.2	28.3	30.0	31.4	28.4	29.8	30.9	27.9	29.7	32.0
18	Max....	29.7	29.9	31.2	29.8	30.1	31.3	28.2	30.0	31.6	28.9	30.0	31.1	28.4	29.9	32.3
	Min....	27.1	28.9	30.9	25.8	28.7	31.2	27.7	29.9	31.3	28.0	29.9	30.7	26.2	29.3	32.2
19	Max....	30.8	30.9	31.3	30.9	31.2	31.7	29.4	30.3	31.7	29.7	30.2	31.2	30.6	30.6	32.7
	Min....	30.2	30.4	30.9	30.4	30.8	31.2	29.0	29.9	31.4	29.0	29.4	30.8	29.8	29.8	32.2
20	Max....	31.9	31.7	31.7	31.7	31.9	32.0	30.1	31.1	31.9	30.7	30.9	31.4	30.9	30.9	32.5
	Min....	31.3	31.3	31.2	31.2	31.3	31.3	29.8	30.8	31.3	30.1	30.6	31.0	30.3	30.1	32.2
21	Max....	32.4	32.9	32.3	32.1	32.5	32.5	31.1	31.7	32.8	31.8	31.7	32.2	31.7	31.3	33.1
	Min....	32.0	32.1	32.1	31.9	32.0	32.2	30.8	31.4	32.3	31.2	31.2	31.8	31.2	31.1	32.7
22	Max....	31.9	32.1	32.6	32.0	32.3	32.2	31.0	31.6	32.6	31.7	31.6	32.2	31.9	31.3	33.2
	Min....	31.8	31.8	31.7	31.3	31.7	31.8	30.3	31.0	31.9	31.0	31.0	31.3	30.9	30.8	32.4
24	Max....	32.0	32.1	32.1	31.8	32.0	32.2	31.0	31.3	32.1	31.7	31.7	31.9	31.4	31.2	32.9
	Min....	32.0	31.9	32.0	31.7	32.0	32.1	31.0	31.3	32.0	31.6	31.6	31.8	31.3	31.1	32.8
25	Max....	31.9	32.1	32.1	31.9	32.2	32.3	31.1	31.6	32.2	31.5	31.7	32.0	31.6	31.3	32.9
	Min....	31.2	31.6	31.3	31.1	31.3	31.6	30.3	30.6	31.6	30.4	31.1	31.2	30.7	30.7	32.4
26	Max....	31.7	31.8	31.8	31.4	31.7	32.0	30.6	31.2	31.8	30.7	31.3	31.7	31.3	31.1	32.6
	Min....	31.5	31.7	31.7	31.2	31.4	31.9	30.4	31.0	31.7	30.6	31.2	31.6	31.2	31.0	32.3
27	Max....	31.9	32.0	32.3	31.9	32.3	32.8	31.1	31.7	32.6	31.4	31.8	32.1	31.8	31.4	33.0
	Min....	31.3	31.6	31.6	31.0	31.2	31.8	30.1	30.9	31.7	30.3	30.9	31.2	30.8	30.7	32.9
28	Max....	31.9	32.2	32.0	31.7	31.9	32.3	30.7	31.3	32.0	31.0	31.4	31.9	31.3	31.2	32.7
	Min....	31.6	31.7	31.7	31.3	31.7	31.9	30.3	31.1	31.8	30.6	31.1	31.4	30.9	30.8	31.9
Ave.	**Max..**	29.35	30.13	31.88	28.97	30.36	32.28	28.75	31.13	32.76	29.03	31.01	32.20	28.48	30.99	33.51
	Min..	27.77	29.30	31.50	26.59	29.58	31.90	27.84	30.77	32.32	28.14	30.58	31.77	26.98	30.56	33.09
	Diff...	1.58	0.83	0.38	2.38	0.78	0.38	0.91	0.36	0.44	0.89	0.43	0.43	1.50	0.43	0.42

TABLE 42.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT WITH SAND, MARCH, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	31.6	31.8	31.9	31.6	31.7	32.2	30.2	31.1	31.8	30.7	31.5	31.6	31.1	31.0	32.4
	Min....	31.4	31.6	31.7	31.2	31.6	32.0	30.1	31.0	31.7	30.4	31.1	31.4	30.8	30.7	32.1
3	Max....	31.7	31.8	31.9	30.9	31.7	32.3	30.0	31.2	31.8	30.3	31.2	31.7	30.2	30.9	32.4
	Min....	31.4	31.7	31.8	30.8	31.6	32.1	30.0	31.0	31.7	30.2	31.0	31.4	30.0	30.8	32.3
4	Max....	31.8	32.0	32.3	31.3	31.9	32.7	30.5	31.6	32.3	31.0	31.6	32.0	30.7	31.2	32.8
	Min....	31.7	31.9	32.1	31.1	31.6	32.2	30.4	31.3	32.1	30.7	31.4	31.8	30.4	31.0	32.6
5	Max....	32.2	32.4	32.8	31.0	31.9	32.9	30.3	31.4	32.2	30.9	31.6	31.9	30.3	31.1	32.7
	Min....	31.4	31.8	32.0	30.6	31.6	32.3	29.9	31.1	31.9	30.4	31.1	31.6	30.0	30.8	32.4
6	Max....	31.8	32.0	32.4	31.1	31.9	32.9	30.3	31.3	32.1	30.7	31.6	31.9	30.3	31.0	32.8
	Min....	31.3	31.7	31.9	30.7	31.4	32.4	29.9	31.0	31.7	30.2	31.1	31.6	29.8	30.6	32.4
7	Max....	31.9	32.1	32.7	31.0	31.9	32.9	30.2	31.4	32.3	30.7	31.7	32.2	29.9	31.1	32.9
	Min....	31.5	31.9	32.2	30.4	31.6	32.6	29.9	31.1	32.0	30.2	31.3	31.8	29.0	30.8	32.5
8	Max....	31.7	32.2	32.7	30.8	31.7	32.7	30.0	31.3	32.3	30.3	31.6	32.1	29.0	30.9	32.9
	Min....	31.3	31.9	32.4	30.3	31.3	32.7	29.8	31.2	32.0	30.1	31.2	31.9	28.9	30.7	32.7
10	Max....	31.8	32.1	32.8	31.8	32.1	32.7	30.7	31.3	32.3	31.3	31.7	32.0	31.0	31.1	32.9
	Min....	31.6	31.9	32.4	31.4	31.9	32.3	30.5	31.2	32.0	31.1	31.4	31.9	30.9	31.0	32.6
11	Max....	32.0	32.5	32.9	32.0	32.3	32.9	31.0	31.9	32.7	31.7	31.9	32.2	31.5	31.3	33.0
	Min....	31.6	31.7	32.2	31.3	31.6	32.0	30.2	31.0	31.9	31.1	31.4	32.0	31.0	30.9	32.7
12	Max....	32.7	32.8	33.1	32.2	32.6	33.1	31.2	31.9	32.9	31.8	32.1	32.7	31.9	31.7	33.3
	Min....	32.0	32.1	32.9	31.9	32.1	32.5	30.9	31.7	32.6	31.4	31.9	32.3	31.4	31.4	32.9
13	Max....	32.7	32.9	33.0	32.0	32.5	33.0	31.3	31.8	32.7	31.9	32.0	32.7	31.8	31.5	33.0
	Min....	32.0	32.4	32.8	31.8	32.1	32.8	30.9	31.6	32.4	31.7	31.9	32.6	31.6	31.4	32.9
15	Max....	33.7	32.7	33.2	33.4	32.6	33.3	32.1	32.1	32.9	33.0	32.4	32.9	32.4	31.9	33.3
	Min....	32.3	32.2	32.7	32.0	32.0	32.7	31.4	31.7	32.2	32.2	31.9	32.2	31.9	31.4	32.9
17	Max....	32.0	32.6	33.1	31.8	32.3	33.2	31.8	31.9	32.8	32.3	32.3	32.7	32.4	31.8	33.2
	Min....	31.5	32.1	32.7	31.1	31.8	32.8	31.4	31.7	32.2	31.9	31.8	32.2	31.8	31.3	32.8
18	Max....	32.7	32.3	32.8	33.8	32.1	32.9	31.6	31.8	32.3	32.0	31.9	32.3	31.9	31.6	32.9
	Min....	31.7	32.2	32.7	31.3	31.9	32.7	31.3	31.4	32.2	31.9	31.8	32.0	31.7	31.1	32.7
19	Max....	44.7	35.9	33.2	46.0	36.0	33.2	35.1	31.8	32.5	36.1	32.6	32.9	32.4	31.9	33.3
	Min....	32.1	32.7	32.7	32.1	32.4	32.8	31.3	31.3	32.0	31.9	31.7	32.2	31.7	31.2	32.7
20	Max....	44.7	39.2	35.4	45.8	39.4	35.9	37.5	32.0	32.8	39.7	32.7	32.8	32.3	31.8	33.1
	Min....	40.9	37.1	34.8	40.9	37.1	34.9	34.7	31.8	32.6	36.3	31.9	32.6	32.0	31.4	33.0
21	Max....	37.9	36.6	35.8	38.2	36.6	36.1	34.8	32.2	32.9	35.9	32.4	32.8	32.3	32.1	33.4
	Min....	34.7	36.0	35.6	34.8	35.8	35.6	32.7	31.9	32.7	34.0	32.3	32.7	32.1	31.8	33.2
22	Max....	35.0	34.2	34.8	35.7	34.4	35.1	32.4	32.2	33.1	33.9	32.6	32.9	32.6	32.1	33.6
	Min....	32.9	33.9	34.3	32.4	33.7	34.2	31.9	32.0	32.8	32.6	32.2	32.7	32.0	31.8	32.9
24	Max....	48.9	41.7	36.9	48.0	40.3	36.7	42.1	31.7	32.7	43.0	32.2	32.9	32.1	31.8	33.3
	Min....	44.2	37.8	34.7	44.6	37.1	34.7	39.8	31.5	32.0	40.9	31.9	32.2	31.8	31.5	32.9
25	Max....	36.3	38.6	38.0	36.1	38.4	37.8	34.1	32.0	33.0	36.1	32.7	32.8	32.1	31.9	33.2
	Min....	34.3	36.4	37.2	34.2	36.4	37.0	32.2	31.8	32.8	33.8	32.6	32.7	31.9	31.5	33.1
26	Max....	33.2	35.7	36.3	32.9	35.2	36.2	31.7	31.9	33.0	32.9	33.2	33.6	31.7	31.3	32.9
	Min....	32.4	34.2	35.2	31.9	34.1	35.2	31.2	31.3	32.6	32.1	32.7	32.9	31.6	31.1	32.8
27	Max....	33.3	34.8	35.8	32.9	34.7	35.7	31.8	31.9	33.3	32.8	33.3	33.7	32.1	31.7	33.3
	Min....	32.1	33.7	34.4	31.8	33.4	34.7	31.0	31.2	32.3	31.8	32.6	33.0	31.3	30.9	32.9
28	Max....	33.0	34.2	35.1	32.7	34.1	35.0	31.7	31.9	33.2	32.8	33.4	33.9	32.1	32.1	33.6
	Min....	32.6	33.8	34.7	32.1	33.6	34.7	31.2	31.4	32.7	32.2	32.9	33.1	31.3	30.7	32.8
29	Max....	32.9	34.1	34.9	32.6	33.9	34.7	31.6	32.3	33.3	32.9	33.8	34.1	32.2	31.8	33.4
	Min....	32.2	33.2	34.1	31.7	33.1	33.8	30.2	31.7	32.9	32.5	33.4	33.6	31.9	31.7	33.3
31	Max....	44.3	40.2	37.8	44.7	39.8	37.2	41.1	31.3	33.0	42.3	37.2	36.0	32.2	31.4	33.3
	Min....	41.2	39.2	37.7	40.4	38.4	36.9	38.8	31.1	32.4	40.6	36.8	35.3	31.6	30.8	32.4
Ave.	Max..	34.98	34.30	34.06	34.81	34.08	34.13	32.61	31.73	32.65	33.48	33.45	32.77	31.54	31.52	33.08
	Min..	33.29	33.41	33.52	32.91	33.17	33.54	31.66	31.40	32.26	32.49	32.05	32.39	31.14	31.13	32.74
	Range	1.69	0.89	0.54	1.90	0.91	0.59	0.95	0.33	0.39	0.99	0.40	0.38	0.40	0.39	0.34

TABLE 43.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, APRIL, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	46.7	42.2	39.4	47.7	42.1	39.2	42.7	33.9	34.9	43.7	38.8	37.8	32.8	32.5	34.6
	Min....	38.9	39.0	38.7	37.9	38.5	38.7	35.0	32.1	34.5	37.8	38.3	37.7	32.2	31.6	33.6
2	Max....	41.8	40.7	39.8	41.1	40.3	39.7	39.6	37.7	36.8	40.2	39.2	38.2	32.6	32.2	33.9
	Min....	39.4	40.0	39.3	38.9	39.6	38.9	37.7	36.8	35.7	38.9	38.7	37.8	32.2	31.8	33.7
3	Max...	51.3	43.0	40.1	50.8	42.2	40.0	47.4	39.2	38.1	46.5	39.3	38.4	33.2	32.0	34.0
	Min....	40.6	40.2	39.8	40.1	39.5	39.6	39.0	38.1	37.8	39.9	38.8	38.0	32.8	31.6	33.9
4	Max ..	52.9	47.2	43.8	52.0	46.8	44.0	51.0	43.8	40.5	50.3	44.2	41.4	35.4	32.7	34.9
	Min....	47.8	46.7	42.0	47.1	45.2	41.6	48.8	42.4	39.2	48.9	42.5	40.2	34.6	31.7	34.0
5	Max....	43.0	42.0	42.8	43.1	42.1	42.9	41.9	43.1	41.2	41.6	43.0	42.1	33.2	32.3	34.9
	Min....	37.4	41.1	41.7	37.7	41.2	42.0	39.2	41.9	40.6	40.0	41.6	41.2	33.0	32.0	34.7
7	Max.. .	44.2	41.5	41.0	45.2	41.6	40.8	41.9	40.1	39.9	41.1	39.8	40.0	33.3	32.2	35.3
	Min....	36.3	38.6	40.0	36.1	39.0	40.1	36.1	39.4	39.7	36.3	39.0	39.4	33.0	31.8	35.1
8	Max....	48.0	42.1	40.3	48.6	41.4	40.6	43.3	39.8	39.8	42.7	39.2	39.6	33.2	32.1	35.8
	Min....	35.1	38.8	39.6	35.1	38.4	39.9	36.0	39.0	39.3	36.1	38.7	39.3	32.6	31.7	35.1
9	Max....	42.1	40.4	40.6	42.2	40.4	40.4	39.0	39.6	39.2	39.5	39.5	39.0	33.1	31.9	35.2
	Min....	37.9	39.6	40.0	37.8	39.6	39.1	36.6	38.9	39.0	37.4	39.0	38.9	32.3	31.4	35.0
10	Max....	44.9	41.0	40.2	44.7	41.0	40.4	42.4	39.2	39.3	42.2	39.2	39.2	33.9	31.9	35.2
	Min....	39.2	39.9	40.0	38.9	39.8	40.1	37.8	39.1	39.1	38.6	39.1	39.0	32.8	31.7	35.0
11	Max....	43.2	42.7	41.3	43.1	42.5	41.2	42.8	41.0	39.8	42.9	41.1	40.2	35.4	32.1	35.9
	Min....	43.0	42.2	41.2	42.8	41.9	41.0	42.2	40.7	39.4	42.6	40.9	40.0	34.7	31.8	35.0
12	Max....	41.4	41.2	41.1	41.2	41.1	41.0	41.0	41.0	40.3	41.0	41.2	40.7	34.6	32.2	35.7
	Min....	40.1	41.1	40.9	39.6	40.8	40.8	40.0	40.7	40.1	40.6	40.8	40.3	34.0	31.8	35.2
14	Max....	52.4	45.4	42.6	53.3	44.9	42.2	48.0	42.0	41.0	47.0	41.9	41.3	35.4	32.2	36.3
	Min....	38.8	42.0	41.8	38.2	41.3	41.7	39.3	41.3	40.7	39.9	41.2	41.0	34.7	31.7	36.1
15	Max....	57.2	46.3	42.7	57.7	45.4	42.7	51.8	42.2	41.2	49.7	42.1	41.8	36.1	32.4	36.8
	Min....	37.5	42.0	42.0	37.3	41.8	42.0	38.3	41.9	41.1	39.1	41.3	41.4	34.9	32.3	36.1
16	Max....	59.1	48.9	44.1	58.8	47.8	43.9	53.8	43.4	41.8	52.3	43.7	42.2	37.3	32.3	37.0
	Min....	43.0	44.7	43.3	42.1	44.1	43.0	42.2	42.9	41.1	42.8	42.9	41.9	36.0	32.1	36.3
17	Max....	61.2	50.5	45.7	60.3	48.8	45.0	55.9	44.7	43.0	54.3	45.0	43.7	38.0	32.7	37.7
	Min....	42.9	46.1	44.8	41.7	45.0	44.4	42.1	44.3	42.9	43.6	44.3	43.1	36.7	32.4	37.0
18	Max....	63.2	53.9	47.2	62.2	51.8	46.6	58.6	46.9	44.0	57.2	47.3	44.8	40.7	32.8	37.6
	Min....	50.0	49.2	46.2	49.0	48.3	46.0	48.3	46.1	43.6	49.0	46.4	44.7	39.2	32.7	37.0
19	Max....	56.3	51.2	48.6	55.8	50.2	47.9	52.9	48.3	45.1	52.6	48.9	46.7	40.9	33.2	38.8
	Min....	46.0	48.6	47.7	45.9	48.0	47.1	45.9	47.4	45.0	47.3	47.4	46.1	40.1	33.0	37.0
21	Max....	53.9	48.0	46.8	53.2	47.3	46.1	50.6	46.0	45.0	49.8	46.3	45.9	41.7	40.0	41.7
	Min....	41.0	45.1	45.7	40.1	44.9	45.3	40.7	45.4	44.9	42.0	45.4	44.9	40.3	38.4	41.2
22	Max....	61.4	51.6	47.0	60.7	50.3	46.6	57.4	46.8	45.0	56.1	46.5	45.4	50.2	42.0	42.8
	Min....	47.9	47.7	46.0	47.2	47.1	45.9	46.2	45.9	44.4	46.6	45.8	45.0	43.3	41.8	42.0
23	Max....	68.3	56.9	50.3	68.9	56.0	49.8	63.9	50.9	46.8	62.3	50.9	48.4	53.7	46.0	44.4
	Min....	54.3	52.3	48.9	53.3	51.0	48.0	53.6	48.8	45.7	53.3	48.9	46.8	50.0	44.0	43.7
24	Max....	68.1	58.7	51.8	68.0	57.4	51.2	64.8	52.2	48.1	63.2	52.4	49.4	56.4	47.8	45.6
	Min....	54.9	54.6	50.9	53.9	53.1	50.0	54.3	51.4	47.9	54.1	51.8	49.1	53.3	47.0	45.0
25	Max....	58.7	56.8	53.5	58.4	56.2	52.8	57.9	54.1	50.3	58.0	54.3	52.1	56.1	50.7	47.9
	Min....	58.0	56.0	53.0	57.3	55.1	52.6	57.1	54.0	49.5	57.0	54.0	51.1	45.4	49.8	46.4
26	Max....	50.6	52.7	52.3	50.4	52.2	51.7	51.0	53.0	50.6	51.7	53.1	51.9	53.6	51.0	48.7
	Min....	49.4	50.2	49.8	49.1	49.6	49.4	49.9	50.6	49.2	50.1	50.6	49.9	51.1	49.9	47.8
28	Max....	50.8	47.0	46.5	52.2	47.1	46.5	49.6	47.0	48.0	48.7	46.8	47.3	47.0	48.3	48.6
	Min....	42.0	45.0	46.4	41.8	44.8	46.4	43.0	46.6	46.7	43.6	46.4	46.8	45.8	48.0	48.4
29	Max....	58.6	49.6	46.6	60.0	49.6	46.9	54.3	46.9	46.8	52.2	46.6	46.9	48.5	47.9	48.2
	Min....	41.2	45.2	46.0	40.8	45.4	46.2	41.8	46.1	46.2	42.5	46.0	46.2	45.6	47.3	47.6
30	Max....	65.9	54.0	48.6	66.4	53.5	48.5	60.7	48.5	46.9	58.2	48.0	47.1	51.9	47.7	47.6
	Min....	45.6	48.2	47.8	44.6	48.0	47.6	45.2	47.6	46.5	45.6	47.3	47.0	47.8	47.5	47.5
Ave.	Max..	53.28	47.52	44.80	53.31	46.92	44.56	50.16	44.28	42.82	49.42	44.55	43.52	40.70	37.35	39.43
	Min..	43.39	44.77	43.98	42.86	44.27	43.75	42.93	43.44	42.30	43.60	43.73	42.95	38.78	36.80	38.82
	Range	9.89	2.75	0.82	10.45	2.65	0.81	7.23	0.84	0.52	5.82	0.82	0.57	1.92	0.55	0.61

TABLE 44.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL. NOT COVERED WITH SAND, MAY, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	70.4	57.6	51.0	69.8	56.6	50.6	64.6	50.7	48.0	62.5	50.8	48.7	55.0	48.7	47.6
	Min....	51.6	52.5	50.1	50.9	52.0	49.8	50.7	50.0	47.7	50.8	49.9	48.6	51.8	48.5	47.5
2	Max....	73.7	60.9	53.5	72.9	59.5	52.9	68.0	53.4	49.8	65.7	53.6	51.1	58.3	50.6	48.5
	Min....	55.9	55.9	52.8	54.8	55.2	52.2	54.7	52.8	49.2	55.0	52.9	50.6	55.1	49.8	48.0
3	Max....	72.0	62.5	55.7	71.0	61.4	54.9	67.9	56.0	51.6	66.6	56.2	53.4	60.6	52.6	49.7
	Min....	59.5	59.0	55.0	58.2	57.9	54.3	58.5	55.4	51.1	58.4	55.5	53.0	58.0	51.8	49.4
5	Max....	70.9	63.3	58.3	70.0	62.1	57.4	68.0	58.9	54.5	66.8	59.1	56.4	62.7	56.0	52.7
	Min....	64.4	62.0	53.0	63.6	60.9	57.1	62.8	58.7	54.2	63.1	58.9	56.0	61.5	55.4	52.0
6	Max....	68.0	62.1	58.4	69.0	61.7	57.5	67.2	59.5	55.4	65.4	59.5	57.0	63.6	57.2	53.9
	Min....	59.6	59.9	57.8	58.5	58.9	56.9	60.6	59.0	55.1	60.9	59.0	56.7	61.4	56.9	53.5
7	Max....	68.9	60.0	57.4	69.2	59.2	56.9	66.4	58.6	55.7	63.5	58.3	57.0	61.1	57.9	54.8
	Min....	50.7	56.0	56.0	49.3	55.4	55.5	52.6	57.2	55.1	53.5	56.8	55.8	58.1	57.4	54.7
8	Max....	66.2	58.7	56.7	66.0	58.1	56.2	63.6	57.6	55.0	61.8	57.1	55.9	59.0	57.4	55.1
	Min....	53.0	55.8	55.6	51.8	55.2	55.1	53.6	56.4	54.6	53.6	55.8	55.0	57.1	56.9	55.0
10	Max....	64.0	57.1	55.5	64.0	56.5	55.4	60.4	56.0	55.0	58.3	55.0	55.5	55.7	57.1	55.8
	Min....	48.0	53.1	53.6	46.4	52.5	53.7	49.2	54.3	53.9	48.9	53.3	53.9	53.5	55.7	55.2
12	Max....	61.4	57.2	55.9	60.7	56.5	55.1	59.4	56.3	54.1	58.0	55.2	54.4	55.4	54.7	54.3
	Min....	52.0	54.9	54.5	51.2	54.3	54.0	53.1	55.0	53.7	52.0	54.1	53.8	53.7	54.3	54.0
13	Max....	65.5	60.1	56.9	64.8	59.5	55.2	64.2	56.5	53.9	62.6	56.3	54.1	58.3	54.3	53.9
	Min....	53.4	55.0	54.8	52.5	54.5	54.0	54.1	55.2	53.6	53.7	54.4	54.0	54.2	54.0	53.6
14	Max....	60.5	57.7	56.4	62.2	58.0	55.5	59.7	57.1	54.4	59.1	56.6	55.0	58.0	54.9	53.8
	Min....	54.9	55.9	55.6	54.0	55.4	54.9	56.3	56.4	54.2	55.9	55.9	54.7	56.1	54.7	53.7
15	Max....	63.2	59.1	56.6	64.9	59.8	55.6	62.0	56.4	54.4	62.6	56.9	55.0	59.8	55.1	54.2
	Min....	52.8	54.4	54.6	52.3	54.1	54.2	53.7	55.0	53.9	53.4	54.9	54.5	55.9	55.0	54.0
16	Max....	65.2	59.2	57.0	68.0	60.0	56.5	62.6	57.5	54.8	62.9	57.4	55.6	60.3	56.1	54.5
	Min....	55.5	56.1	56.2	55.2	56.0	55.6	56.8	56.7	54.4	56.6	56.5	55.3	57.7	55.9	54.4
17	Max....	64.7	60.1	57.8	66.2	60.6	56.9	61.8	57.4	54.9	61.9	57.6	55.9	60.8	56.6	55.0
	Min....	53.8	55.9	55.9	53.3	56.1	55.4	54.9	56.4	54.7	54.3	56.1	55.4	57.5	56.2	54.9
19	Max....	70.0	62.9	58.9	70.0	62.6	57.1	67.0	57.7	55.4	64.0	57.3	55.9	61.6	56.9	55.5
	Min....	52.5	55.5	55.8	51.1	55.3	55.4	53.1	55.7	54.8	51.4	54.8	55.1	56.3	56.2	55.4
20	Max....	62.4	60.1	59.0	62.0	59.6	58.1	61.0	59.0	55.9	58.5	57.9	56.3	59.4	57.0	55.5
	Min....	58.6	59.3	58.4	57.6	58.6	57.4	58.6	58.3	55.7	56.7	57.2	56.0	58.6	56.8	55.5
21	Max..	65.5	60.8	58.3	65.8	60.7	57.0	63.6	58.0	55.9	63.2	57.6	56.0	60.2	56.8	55.7
	Min....	56.1	57.1	56.9	55.3	56.5	56.1	55.9	56.9	55.4	54.1	55.9	55.5	57.0	56.5	55.5
22	Max....	59.8	59.3	58.8	58.4	59.0	58.0	59.5	59.0	56.1	58.9	58.7	56.8	60.3	57.4	55.9
	Min....	58.1	58.3	58.0	57.8	58.0	57.1	58.5	58.4	56.0	57.9	58.0	56.7	59.6	57.0	55.7
23	Max....	58.2	57.0	56.1	58.4	56.8	55.9	57.9	56.9	56.0	57.4	56.1	56.2	58.0	57.3	56.1
	Min....	53.3	55.0	55.3	52.5	54.5	55.1	54.3	56.0	55.2	53.7	55.5	55.4	56.6	56.6	56.0
24	Max....	67.1	61.6	58.0	68.1	62.0	56.6	65.2	57.2	55.0	63.4	57.5	5.53	61.5	56.6	56.0
	Min....	53.4	54.6	55.1	52.7	54.1	54.6	53.9	55.3	54.5	53.4	55.0	54.8	56.3	56.2	55.6
26	Max...	53.7	53.5	55.2	53.4	53.2	55.2	53.5	56.0	55.5	53.3	54.9	55.6	55.3	57.0	55.9
	Min....	49.7	53.0	53.8	48.5	52.4	53.8	51.2	54.2	54.4	50.1	53.5	54.5	54.1	55.9	55.5
27	Max....	66.2	59.1	55.7	67.7	60.0	54.9	63.0	54.9	53.8	61.8	55.2	53.8	58.8	55.2	55.4
	Min....	50.5	52.0	53.0	49.9	51.7	53.0	51.0	53.3	53.1	50.9	52.9	53.4	53.5	54.7	54.9
28	Max....	74.1	64.1	59.2	74.4	64.4	57.4	69.5	57.7	54.2	67.7	58.2	54.8	62.5	55.5	54.9
	Min....	54.0	55.7	55.7	53.3	55.6	55.0	54.4	55.5	54.0	53.7	55.0	54.5	56.7	55.2	54.6
29	Max....	68.0	63.0	60.9	68.0	62.6	59.1	64.6	60.4	56.4	63.4	60.0	57.2	62.5	57.3	55.4
	Min....	60.7	61.2	59.7	59.7	60.6	58.4	61.0	59.4	55.9	59.5	58.7	56.9	60.7	56.8	55.0
30	Max....	64.8	59.9	59.2	65.0	59.5	58.4	63.0	59.6	57.0	63.1	59.0	57.7	60.6	57.9	56.1
	Min....	56.7	58.2	58.2	55.4	57.5	57.1	58.1	58.5	56.7	57.5	58.1	57.1	59.1	57.5	55.9
31	Max....	71.9	63.5	60.0	74.5	64.1	58.5	68.2	59.5	57.0	67.7	60.0	57.5	63.8	58.0	56.6
	Min...	58.1	58.7	58.2	57.4	58.3	57.5	59.0	58.7	56.7	58.6	58.5	57.3	59.9	57.9	56.5
Ave.	Max..	66.01	60.02	57.17	66.32	59.77	56.26	63.53	57.22	54.60	62.31	57.00	55.31	59.73	55.85	54.34
	Min..	54.88	56.35	55.72	53.97	55.83	55.12	55.41	56.10	54.15	54.91	55.66	54.79	56.92	55.38	54.08
	Range	11.13	3.67	1.45	12.35	3.94	1.14	8.12	1.12	0.45	7.40	1.34	0.52	2.81	0.47	0.26

TABLE 45.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JUNE, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2	Max....	78.5	69.4	64.5	78.2	68.9	62.1	74.8	63.4	58.9	71.7	63.1	60.0	67.5	60.2	57.8
	Min....	59.5	62.1	61.5	58.4	61.9	60.5	60.4	61.5	58.8	58.5	60.6	59.5	62.3	60.0	57.0
3	Max....	78.1	70.9	66.3	77.5	69.9	63.5	75.8	65.5	60.4	73.5	65.1	61.0	68.8	61.3	58.7
	Min....	64.1	64.8	63.7	63.2	64.0	62.1	64.2	63.7	60.1	62.2	62.6	61.0	64.5	61.1	58.4
4	Max....	77.9	70.2	66.0	77.0	69.0	63.5	75.8	65.5	61.6	73.0	64.9	62.4	68.4	62.4	60.5
	Min....	61.3	64.2	63.7	59.8	63.6	62.2	62.5	64.0	61.4	60.2	62.6	61.6	63.9	62.0	60.4
5	Max....	78.2	70.4	66.2	77.0	69.1	63.7	76.1	66.0	62.2	73.6	65.3	62.7	68.3	62.8	61.3
	Min....	62.2	64.5	64.0	60.9	63.7	62.5	63.4	64.5	61.9	61.2	63.1	62.1	64.4	62.4	61.1
6	Max....	80.8	72.9	68.3	79.5	71.6	65.4	78.6	68.0	62.7	77.1	67.7	63.3	70.7	63.4	61.9
	Min....	66.8	66.7	65.7	66.2	66.0	63.9	67.0	66.0	62.6	65.1	65.1	63.0	66.5	63.2	61.5
7	Max....	65.0	67.3	67.5	64.5	66.3	66.0	66.6	68.5	63.9	65.1	67.5	64.9	68.0	64.5	62.6
	Min....	63.4	64.9	64.6	61.5	63.8	63.5	65.0	65.7	63.5	64.4	64.9	64.0	66.0	64.2	62.3
9	Max	70.6	64.3	61.4	70.5	63.8	59.8	68.9	61.5	60.7	67.5	60.8	61.6	63.1	62.2	62.1
	Min....	53.0	57.9	58.7	50.9	57.0	58.4	55.1	59.9	59.5	53.2	54.4	59.1	58.7	61.0	61.0
10	Max	75.5	66.9	62.8	74.9	66.3	60.8	73.0	62.5	60.0	71.6	62.2	60.0	64.9	61.2	60.9
	Min....	54.8	58.9	59.5	52.9	58.1	58.8	56.6	60.1	59.3	54.5	58.6	59.3	59.4	60.4	60.1
11	Max....	77.7	69.0	64.7	76.6	67.9	62.4	74.9	64.0	60.5	73.7	64.0	60.9	66.2	61.2	60.0
	Min....	58.9	62.0	61.8	57.3	61.3	60.8	60.2	62.2	60.2	58.2	61.0	60.6	61.7	60.8	59.8
12	Max....	79.0	70.5	66.1	77.4	69.0	63.4	76.4	65.5	61.5	75.4	65.4	62.0	67.5	61.6	60.2
	Min....	60.8	63.5	63.2	59.0	62.7	61.9	62.0	63.5	61.4	60.0	62.5	61.7	62.7	61.5	60.1
13	Max....	81.1	72.3	67.6	79.2	70.7	64.7	78.6	67.0	62.6	77.6	67.2	63.2	69.1	62.5	60.9
	Min....	63.2	65.1	64.7	62.4	64.3	63.2	64.1	65.0	62.5	62.6	64.0	62.9	64.1	62.3	60.6
14	Max....	84.9	74.6	69.2	82.8	72.7	66.0	81.6	68.9	63.6	81.1	69.1	64.5	71.2	63.5	61.5
	Min....	65.4	67.0	66.5	63.9	66.2	64.5	66.5	66.7	63.5	64.8	66.0	64.2	65.8	63.4	61.2
16	Max....	90.4	80.3	74.5	86.9	77.6	70.0	87.3	73.9	67.0	86.8	74.6	68.4	76.6	67.1	64.1
	Min....	73.1	73.0	71.3	71.1	71.7	68.6	73.6	71.6	66.8	72.4	71.2	68.1	71.3	66.7	63.5
17	Max....	87.6	79.6	74.8	87.5	78.9	71.2	85.9	74.8	68.6	84.3	75.0	70.1	78.5	69.1	65.6
	Min....	72.9	73.9	72.5	70.8	72.4	69.7	74.4	73.2	68.6	73.4	72.8	69.9	73.4	68.6	65.1
18	Max...	87.4	78.7	74.2	86.6	77.7	71.2	85.4	74.5	69.5	83.7	74.1	70.7	77.9	70.2	67.0
	Min....	71.0	73.2	72.0	69.9	72.1	70.0	73.1	73.1	69.1	70.9	71.8	69.9	73.5	70.1	66.5
19	Max	83.0	77.8	74.4	81.5	76.6	71.7	82.4	75.0	70.0	80.9	74.4	70.8	77.6	71.1	67.9
	Min....	73.2	74.0	72.9	72.2	72.9	70.6	74.7	73.9	69.6	72.5	72.4	70.4	74.3	70.9	67.6
20	Max	78.1	74.4	72.6	78.0	73.6	70.7	77.3	74.0	70.2	76.0	72.9	70.8	75.7	71.7	68.6
	Min....	70.8	72.4	71.6	69.2	71.0	69.8	72.6	73.4	69.6	71.9	71.9	70.0	73.9	71.2	68.4
21	Max	73.1	70.9	70.5	74.1	70.1	68.6	73.2	72.0	69.4	72.7	70.9	69.7	72.6	71.3	68.8
	Min....	69.0	69.5	69.5	68.1	68.5	68.3	70.7	70.8	68.5	70.0	70.1	68.8	71.8	70.7	68.6
23	Max...	85.9	76.1	71.2	85.9	75.6	69.0	82.5	71.0	67.6	80.4	70.5	67.9	75.4	69.6	67.9
	Min....	66.6	68.8	68.5	65.7	68.2	67.6	68.0	69.4	67.0	66.2	68.0	67.2	69.9	69.1	67.6
24	Max..	86.1	77.6	73.1	83.6	76.9	70.6	83.6	72.8	68.7	81.7	72.2	68.9	76.6	70.0	68.2
	Min....	71.0	71.6	70.9	69.7	70.8	69.4	71.4	71.3	68.1	69.4	69.9	68.5	71.8	69.6	67.9
25	Max..	87.0	79.4	75.2	84.5	78.4	72.4	84.9	75.0	69.6	83.5	74.6	70.1	78.2	70.9	68.8
	Min....	74.7	74.5	72.9	73.0	73.5	71.1	75.1	73.5	69.4	73.4	72.4	70.0	74.6	70.7	68.1
26	Max....	88.8	80.5	76.4	84.7	78.5	73.4	86.3	76.2	71.3	85.0	75.9	71.5	79.7	72.1	69.0
	Min....	76.0	75.4	74.3	74.6	74.6	72.2	76.5	74.8	70.6	74.9	74.0	71.2	75.8	72.0	68.8
27	Max...	92.1	83.8	78.8	90.0	82.2	75.2	90.1	78.4	72.0	88.4	78.4	73.0	82.0	73.6	70.2
	Min....	77.8	77.2	75.9	76.5	76.1	73.6	78.0	76.4	71.8	76.6	75.6	72.7	77.4	73.3	69.7
28	Max...	95.5	85.1	80.1	92.0	83.5	76.2	93.0	80.0	73.4	91.4	79.8	74.4	83.3	74.9	71.3
	Min....	79.6	79.0	77.7	78.2	77.9	75.0	79.9	78.1	73.3	78.2	77.3	73.1	78.7	74.6	70.8
30	Max....	92.0	84.9	80.6	89.5	82.7	77.5	90.7	81.0	75.8	89.0	80.4	76.6	83.1	77.4	73.5
	Min....	79.5	80.3	76.4	77.9	78.5	76.6	80.5	79.9	75.4	78.3	78.5	76.1	79.8	77.0	73.4
Ave.	Max..	82.17	74.71	70.68	80.80	73.54	67.96	80.15	70.60	66.07	78.59	70.24	66.78	73.24	67.03	64.77
	Min.	67.54	68.98	68.16	66.13	68.03	66.59	68.62	68.89	65.70	66.92	67.65	66.20	69.05	66.67	64.38
	Range	14.63	5.73	2.52	14.67	5.51	1.37	11.53	1.71	0.37	11.67	2.59	0.58	4.19	0.36	0.39

TABLE 46.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JULY, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	**Max**....	88.5	82.5	79.5	86.7	81.1	77.0	87.4	80.4	75.9	85.6	79.4	76.7	82.0	77.7	74.4
	Min....	78.2	79.1	78.1	77.0	77.7	76.1	79.8	79.5	75.4	78.1	78.3	75.9	79.9	77.4	74.0
2	**Max**....	91.9	84.4	80.1	89.3	82.5	76.6	90.6	80.4	75.7	88.4	79.8	76.0	82.9	77.4	74.5
	Min....	76.3	77.8	77.0	74.9	76.8	75.4	77.6	78.3	74.9	75.4	76.9	75.2	78.3	76.9	74.1
3	**Max**....	94.1	84.9	80.4	90.1	82.4	77.1	91.6	80.5	75.9	90.1	80.1	76.4	82.9	77.6	74.8
	Min....	78.0	79.4	78.0	76.4	77.6	76.1	79.2	79.2	75.5	77.0	77.8	75.9	79.0	77.1	74.2
4	**Max**....	88.6	85.0	81.8	85.6	83.0	78.4	88.7	82.2	76.5	86.9	81.6	77.1	83.9	77.9	74.7
	Min....	81.6	81.2	79.8	80.1	80.0	77.5	82.3	80.6	76.4	80.4	79.5	76.9	80.6	77.7	74.5
5	**Max**....	81.0	78.9	79.2	79.5	77.9	77.1	81.1	80.5	76.9	80.5	79.2	77.3	79.8	78.2	75.1
	Min....	78.1	77.9	77.7	76.5	77.0	75.9	79.2	79.0	75.9	78.4	78.2	76.3	79.0	77.7	75.0
7	**Max**....	82.2	74.8	72.1	81.1	74.2	71.0	79.6	73.0	72.9	77.6	71.3	72.5	74.6	75.1	74.1
	Min....	63.7	68.6	69.9	61.1	67.3	69.6	66.1	71.5	71.2	64.1	69.6	70.8	69.5	73.4	73.3
8	**Max**....	77.7	75.1	73.1	76.7	74.5	71.6	77.6	73.4	71.2	75.5	72.3	71.1	74.8	73.1	72.4
	Min....	67.8	70.5	70.9	65.9	69.8	70.0	68.9	71.7	70.6	66.9	69.9	70.4	70.5	72.2	71.7
9	**Max**...	84.9	76.9	73.3	83.5	76.5	71.3	82.3	73.1	70.7	80.6	72.5	70.6	76.1	72.1	71.2
	Min....	68.9	70.5	70.4	67.5	69.8	69.9	70.0	71.4	70.1	68.6	70.1	70.1	71.2	71.7	70.9
10	**Max**....	85.4	77.0	73.5	80.7	76.3	71.8	83.1	73.5	71.0	81.2	72.5	71.1	75.7	72.1	70.7
	Min....	67.9	71.4	71.0	66.0	70.5	70.6	69.5	72.0	70.5	67.1	70.4	71.4	71.3	71.7	70.6
11	**Max**....	84.7	77.2	73.9	83.2	76.1	72.0	82.8	73.9	71.1	81.0	73.0	71.6	75.4	72.0	70.5
	Min....	68.3	71.7	71.2	66.3	70.7	70.8	70.0	72.5	70.6	67.5	70.7	70.9	71.1	71.6	70.4
12	**Max**....	81.9	76.5	74.1	81.6	76.1	72.6	80.2	74.5	71.4	78.6	73.4	71.5	75.3	72.0	70.5
	Min....	73.1	73.7	73.0	70.8	72.9	71.9	74.3	73.9	71.2	72.5	72.4	71.4	73.1	71.9	70.4
14	**Max**....	87.6	79.5	75.4	85.8	78.4	73.1	84.8	75.1	71.7	83.2	74.4	72.1	76.8	72.5	70.7
	Min....	71.2	73.7	72.1	69.5	72.8	72.0	72.1	73.6	71.4	70.5	72.2	71.6	72.4	72.0	70.6
15	**Max**....	89.1	80.0	76.1	86.0	79.1	74.1	85.8	76.0	72.3	84.4	75.4	72.9	78.4	72.9	70.9
	Min....	75.0	74.7	74.4	71.0	73.7	72.9	74.5	74.8	72.1	72.9	73.6	72.5	73.8	72.7	70.8
16	**Max**....	86.0	79.9	76.7	84.0	78.8	74.8	84.5	76.8	73.0	83.1	76.0	73.8	78.2	73.8	71.5
	Min....	74.9	75.9	75.2	72.0	75.0	74.0	75.7	75.4	72.9	73.7	74.4	73.2	75.5	73.6	71.2
17	**Max**....	78.3	75.3	75.3	78.0	74.9	74.3	77.7	76.2	73.7	77.5	75.1	73.8	75.7	74.0	72.1
	Min....	73.0	74.1	74.3	70.5	73.1	73.4	74.2	75.1	72.9	73.8	74.3	73.1	73.6	73.6	71.9
18	**Max**....	85.6	78.2	75.0	87.2	79.3	73.7	82.1	74.5	72.4	80.0	74.5	72.8	78.2	73.9	72.1
	Min....	71.5	72.9	72.8	70.4	72.3	72.2	73.0	74.0	71.9	72.4	73.1	72.4	74.2	73.5	72.0
19	**Max**....	86.1	79.1	75.8	86.0	79.0	74.1	82.8	75.0	72.3	80.9	74.5	73.0	76.9	74.1	72.1
	Min....	71.3	73.8	73.7	70.0	73.6	73.0	72.3	74.0	72.0	71.0	72.9	72.3	73.6	73.5	72.0
21	**Max**....	86.4	78.5	74.8	84.9	77.6	73.0	83.3	74.4	72.4	81.2	73.5	72.5	77.0	73.2	71.7
	Min....	68.5	72.1	72.4	66.6	71.3	71.7	69.9	73.0	71.5	68.0	71.4	71.5	71.4	72.3	71.6
22	**Max**....	84.0	77.5	74.6	82.8	75.7	73.1	81.4	74.5	72.4	79.7	73.0	72.5	75.5	73.0	71.5
	Min....	68.8	72.4	72.6	66.5	71.2	71.7	70.0	73.0	71.6	67.7	71.1	71.3	71.0	72.1	71.2
23	**Max**....	71.9	73.6	74.1	70.5	72.4	73.0	72.3	74.4	71.9	70.5	72.8	72.0	72.5	72.5	71.1
	Min....	70.8	71.7	72.1	69.2	71.0	71.4	71.5	72.6	71.4	70.1	71.1	71.1	71.5	71.9	71.0
24	**Max**....	77.6	73.5	71.3	77.0	73.3	70.0	77.0	71.1	70.6	75.4	70.5	70.4	73.4	71.3	70.8
	Min....	65.5	68.1	69.1	63.9	67.0	68.8	66.6	69.9	69.5	65.7	68.6	69.4	68.7	70.5	70.4
25	**Max**....	82.0	74.5	71.3	81.2	72.5	69.9	79.7	71.0	69.8	78.1	70.5	69.8	73.8	70.8	70.1
	Min....	64.0	68.1	68.8	61.9	67.8	68.6	65.7	69.5	69.0	64.0	68.1	69.0	68.5	70.0	69.9
26	**Max**....	87.0	78.0	74.0	85.0	75.6	71.6	83.9	73.1	69.8	82.6	72.9	70.0	76.5	70.6	69.6
	Min....	70.4	71.6	71.6	68.5	70.1	70.5	70.9	71.5	69.7	69.3	70.5	69.7	71.2	70.5	69.5
28	**Max**....	86.8	79.6	76.1	87.5	80.0	74.1	84.1	75.9	72.1	82.8	75.8	73.0	80.4	73.1	70.8
	Min....	73.0	74.5	74.3	69.1	73.4	72.8	74.3	74.6	72.0	73.5	74.0	72.6	74.9	72.9	70.5
29	**Max**....	89.9	80.6	76.9	89.1	80.4	74.8	85.6	76.5	73.0	84.5	76.2	73.8	80.5	74.4	71.8
	Min....	74.5	75.8	75.2	72.7	75.2	74.0	75.6	75.6	72.7	74.6	74.8	73.4	76.7	74.2	71.5
30	**Max**....	93.9	84.0	79.4	92.0	83.4	76.7	89.9	78.5	73.9	88.9	78.6	74.6	83.5	75.5	72.9
	Min....	76.6	78.0	77.1	74.3	77.0	75.2	77.5	77.1	73.9	75.9	76.1	74.5	78.1	75.4	72.4
31	**Max**....	86.0	81.9	79.6	83.5	81.1	77.6	84.4	79.5	75.1	83.0	78.6	76.2	81.2	76.9	73.8
	Min....	77.2	79.4	78.3	74.2	78.1	76.4	78.2	78.4	75.0	76.5	77.4	75.8	78.9	76.6	73.5
Ave.	**Max**..	85.15	78.77	75.83	83.65	77.85	73.87	83.12	75.85	72.80	81.55	75.09	73.14	77.85	73.99	72.09
	Min..	72.08	74.02	73.74	70.10	73.06	72.68	73.29	74.51	72.29	71.69	73.24	72.50	73.98	73.50	71.82
	Range	13.07	4.75	2.09	13.55	4.79	1.19	9.83	1.34	0.51	9.86	1.85	0.64	3.87	0.49	0.27

TABLE 47.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, AUGUST, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	86.1	79.6	77.0	86.1	79.4	75.7	84.5	77.7	75.4	82.6	76.5	75.8	80.6	76.8	74.1
	Min....	71.5	75.4	75.3	68.9	74.3	74.1	73.9	76.3	74.4	72.5	75.1	74.5	76.5	76.0	74.0
2	Max....	89.8	80.6	76.9	89.1	80.4	74.9	86.8	77.1	74.5	85.1	76.4	74.8	81.1	76.5	74.3
	Min....	70.4	74.1	74.4	63.4	73.0	73.5	72.6	75.5	73.8	70.8	74.0	73.8	75.5	75.8	74.0
4	Max....	85.0	77.7	74.8	84.3	77.5	73.5	83.0	75.4	73.8	81.4	74.1	73.9	78.1	75.5	74.0
	Min....	67.9	72.4	72.9	65.4	71.4	72.2	70.3	73.8	72.8	73.5	72.2	72.6	73.6	74.6	73.6
5	Max....	84.0	77.1	74.1	82.5	76.4	73.4	81.6	74.8	73.2	80.0	73.3	73.2	76.3	74.9	73.4
	Min....	67.2	72.0	72.4	64.8	71.0	71.6	69.4	73.3	72.1	67.3	71.4	72.0	72.1	73.9	73.1
6	Max....	78.8	75.4	74.4	77.8	74.6	73.5	77.5	75.0	72.6	76.2	73.3	72.7	74.8	74.0	72.8
	Min....	71.8	73.7	73.5	70.0	72.6	72.5	72.8	74.0	72.1	71.0	72.5	72.0	73.4	73.5	72.5
7	Max....	84.8	77.6	74.3	84.1	77.0	72.6	82.5	74.3	72.1	81.4	73.8	72.1	76.8	73.5	72.3
	Min....	69.3	71.4	72.0	67.4	71.2	71.4	70.5	72.6	71.7	69.2	71.4	71.7	72.5	73.0	72.2
8	Max....	85.4	78.3	75.5	84.9	78.0	74.0	82.8	75.4	72.5	82.2	74.7	72.9	78.0	73.9	72.2
	Min....	73.6	74.3	74.1	72.4	73.8	73.3	74.8	74.5	72.3	73.4	73.5	72.5	74.8	73.7	72.1
9	Max....	81.7	76.8	75.4	82.4	77.1	75.1	80.0	76.0	73.4	79.9	74.9	73.5	77.4	75.0	73.1
	Min....	72.7	74.2	74.4	71.0	74.0	74.0	74.4	75.0	73.0	73.6	74.0	73.1	74.6	74.5	72.7
11	Max....	74.9	71.0	70.8	78.0	72.5	71.3	73.2	72.1	72.4	72.3	70.8	72.0	73.1	75.1	74.6
	Min....	63.5	68.4	69.4	61.7	67.9	69.9	66.0	70.7	71.0	65.2	69.5	70.5	70.5	73.7	73.9
12	Max....	80.7	73.5	70.8	82.1	74.4	70.7	77.5	70.6	70.4	76.1	70.0	70.1	73.7	73.2	73.3
	Min....	66.7	68.6	69.4	66.2	69.1	70.0	67.7	70.0	69.5	67.0	69.0	69.5	70.2	72.3	72.4
13	Max....	86.6	77.6	73.6	86.8	78.1	72.1	82.8	72.4	70.0	81.8	72.5	70.2	76.7	72.4	71.7
	Min....	68.2	70.6	70.9	66.9	70.5	70.6	69.0	70.7	69.6	68.0	70.0	69.9	70.9	71.8	71.4
14	Max....	87.6	79.7	76.0	87.6	79.5	74.0	84.5	74.8	71.1	83.6	74.8	71.7	79.0	72.6	71.1
	Min....	73.5	74.5	73.9	72.4	74.2	73.0	73.8	73.5	70.9	72.5	72.9	71.6	74.0	72.5	71.1
15	Max....	90.7	81.4	77.5	89.9	81.2	75.3	87.0	76.6	72.5	86.2	76.8	73.5	81.5	74.0	71.8
	Min....	75.7	76.3	75.5	74.2	75.6	74.3	76.4	75.4	72.5	75.3	74.9	73.4	76.5	73.9	71.5
16	Max....	88.5	84.5	80.1	85.9	83.9	77.5	89.3	80.3	74.8	87.5	79.5	75.0	85.9	75.7	72.9
	Min....	77.5	78.2	77.4	75.8	77.5	75.6	77.8	77.1	73.8	76.8	76.6	74.8	78.4	75.5	72.5
18	Max....	82.4	78.8	76.5	84.3	79.4	75.0	82.4	76.9	74.9	82.0	76.6	74.9	81.0	77.2	75.4
	Min....	73.0	74.6	74.9	71.2	73.8	74.0	74.5	75.8	74.0	73.9	75.0	74.2	76.6	76.6	75.1
19	Max...	84.1	78.1	75.5	85.9	79.1	74.9	82.1	76.4	74.3	80.3	75.4	74.6	79.1	77.1	75.2
	Min....	70.6	73.7	73.9	69.2	73.9	73.8	73.1	75.0	73.4	72.0	74.1	73.7	76.1	76.1	74.9
20	Max....	84.4	77.6	74.9	85.0	78.0	74.5	81.7	75.4	73.7	80.5	74.0	73.9	78.5	76.1	74.7
	Min....	68.6	72.8	73.1	66.7	72.5	73.1	70.4	73.9	72.8	68.9	72.4	72.7	73.5	75.0	74.3
21	Max....	78.8	75.6	75.0	78.8	75.4	74.5	78.0	75.4	73.3	77.5	74.3	73.5	76.5	75.4	74.0
	Min....	73.8	74.2	74.4	72.1	74.0	73.6	74.1	74.5	72.9	72.9	73.6	72.9	75.1	74.7	73.6
22	Max....	76.2	74.5	73.9	78.0	75.3	73.4	76.4	74.5	72.6	75.7	73.8	73.0	76.2	74.7	73.4
	Min....	71.4	73.0	73.1	69.8	72.8	72.7	72.9	73.7	72.1	72.3	73.1	72.4	74.9	74.3	73.3
23	Max...	78.5	74.1	72.0	79.0	74.9	71.7	77.0	72.1	71.9	75.9	71.5	72.0	74.0	74.0	73.3
	Min....	65.9	69.3	70.1	64.9	69.4	70.7	67.7	71.1	70.8	67.0	70.1	70.9	70.6	72.8	72.7
25	Max....	74.9	71.4	70.5	74.6	71.4	70.7	73.3	70.9	70.4	72.4	69.8	70.5	70.6	71.4	71.2
	Min....	63.6	68.5	69.3	61.5	67.9	69.2	65.4	69.5	69.4	64.0	68.3	69.3	67.5	70.4	70.7
26	Max....	82.9	75.5	72.2	82.6	75.6	71.0	79.8	71.3	69.3	79.0	71.3	69.5	74.8	70.2	70.3
	Min....	68.1	69.5	69.9	67.1	69.4	69.6	68.5	69.8	69.0	67.6	69.0	69.2	69.3	69.9	69.8
27	Max....	83.1	75.7	72.6	82.7	75.4	71.3	80.3	71.8	70.0	79.4	71.5	70.4	75.1	70.7	69.8
	Min....	67.2	70.6	70.6	65.5	69.9	70.2	68.0	70.5	69.4	67.0	69.7	69.9	69.9	70.2	69.5
28	Max....	73.4	71.5	72.0	73.0	71.0	71.5	72.6	72.0	70.2	71.7	71.1	70.5	71.5	70.8	69.9
	Min....	69.0	70.2	71.0	67.5	69.6	70.1	69.5	70.8	69.8	68.7	70.0	69.9	70.3	70.4	69.6
29	Max...	75.1	71.0	69.5	74.1	70.6	69.3	73.4	69.9	69.5	72.5	68.8	69.6	71.0	70.2	69.8
	Min....	63.5	67.5	68.2	62.0	67.0	68.4	65.0	68.6	68.6	64.1	67.5	68.5	68.0	69.6	69.5
30	Max...	76.4	72.1	70.1	75.6	72.0	69.1	75.0	69.5	68.8	74.0	69.2	68.9	71.6	69.7	69.5
	Min....	64.1	67.5	68.0	62.6	67.2	68.1	65.3	68.1	68.0	64.3	67.3	68.1	68.0	69.0	69.0
Ave.	Max..	82.05	76.41	74.07	82.16	76.46	73.08	80.20	74.18	72.22	79.12	73.41	72.41	76.65	73.87	72.62
	Min..	69.55	72.13	72.38	67.72	71.67	71.90	70.92	72.83	71.53	69.95	71.81	71.68	72.82	73.22	72.27
	Range	12.50	4.28	1.69	14.44	4.79	1.18	9.28	1.35	0.69	9.17	1.60	0.73	3.83	0.65	0.35

TABLE 48.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, SEPTEMBER, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	78.2	71.8	70.2	78.0	71.5	69.6	75.1	70.0	68.4	74.8	69.5	68.8	71.0	69.3	68.7
	Min....	68.8	69.5	69.5	67.8	69.2	69.1	69.1	69.5	68.3	68.5	69.0	68.5	69.3	69.2	68.2
2	Max....	85.7	76.9	72.8	85.0	76.4	70.9	82.1	71.6	68.7	81.9	71.8	69.3	76.2	69.8	69.0
	Min....	68.5	70.0	70.1	67.5	69.5	69.4	68.9	69.9	68.6	67.9	69.2	69.0	69.5	69.6	68.8
3	Max....	84.0	78.1	75.0	83.1	77.5	72.8	82.0	74.0	70.2	81.5	74.1	71.1	78.1	71.2	69.5
	Min....	73.2	74.0	73.1	71.7	73.4	72.0	73.4	73.5	69.9	72.5	71.9	70.9	73.9	71.1	68.8
4	Max....	77.6	74.6	74.3	76.9	74.0	73.1	76.6	74.1	71.1	75.9	73.5	72.0	75.3	72.4	70.4
	Min....	72.0	73.0	73.0	71.3	72.5	72.1	72.8	73.2	70.9	71.6	72.1	71.5	73.6	72.0	70.0
5	Max....	83.0	75.7	72.6	82.0	74.9	71.1	80.4	72.4	71.0	79.7	72.0	71.2	76.1	72.2	70.7
	Min....	68.0	70.4	70.7	67.0	70.0	70.2	68.8	71.0	70.1	68.0	70.1	70.5	71.4	71.5	70.5
6	Max....	83.5	77.5	73.9	82.4	76.2	71.6	81.7	73.4	70.6	80.7	73.0	71.1	77.3	72.0	70.7
	Min....	67.4	71.0	71.0	66.4	70.3	70.5	68.8	71.4	70.1	67.5	69.7	70.5	71.4	71.5	70.1
8	Max....	75.6	73.6	73.6	75.6	73.4	72.4	75.6	74.0	71.6	74.8	72.4	72.0	74.9	72.9	71.1
	Min....	70.5	72.1	72.5	69.0	71.3	71.6	72.1	72.9	71.1	71.5	72.0	71.5	73.4	72.5	71.0
9	Max....	75.9	71.1	69.7	76.1	71.0	69.7	74.2	70.7	70.8	73.1	69.3	70.9	72.0	72.3	71.2
	Min....	61.5	67.0	68.4	59.0	66.1	68.2	63.9	69.1	69.5	62.9	67.1	69.2	67.9	70.9	70.8
10	Max....	75.6	70.0	68.1	75.5	69.6	68.5	73.4	68.9	69.3	72.3	67.5	69.1	70.5	70.7	70.2
	Min....	60.0	65.5	66.7	58.1	64.7	67.0	62.0	67.3	67.9	60.8	65.0	67.6	66.0	69.3	70.0
11	Max....	76.6	70.5	68.4	76.4	70.1	67.9	74.0	67.9	68.0	73.1	66.8	68.0	70.4	69.3	69.5
	Min....	61.5	65.8	66.5	59.9	65.4	66.7	62.9	66.8	67.1	61.5	65.1	66.9	66.0	68.4	68.9
12	Max....	74.8	70.9	69.0	74.2	70.4	68.6	73.5	68.8	67.6	72.3	67.8	67.9	70.9	68.8	68.3
	Min....	64.5	67.2	67.7	63.6	66.8	67.7	65.6	67.7	67.2	64.6	66.5	67.3	67.8	68.3	68.0
13	Max....	70.6	68.5	67.4	70.2	68.1	67.6	70.3	67.5	67.5	69.0	66.4	67.5	68.5	68.5	68.1
	Min....	59.3	64.6	65.9	58.6	64.1	66.4	61.5	66.1	66.5	59.9	64.7	66.4	65.1	67.4	67.9
15	Max....	70.0	65.9	64.6	69.1	65.2	65.2	68.1	64.9	65.5	67.4	63.5	65.3	65.1	66.2	66.5
	Min....	56.8	62.0	63.2	56.0	61.7	64.0	58.6	63.5	64.4	57.2	61.9	64.1	61.9	65.1	66.4
16	Max....	64.4	64.6	65.3	64.1	64.5	65.2	64.0	65.0	64.6	63.9	64.1	64.6	64.5	65.3	65.5
	Min....	63.0	64.0	64.5	62.6	63.7	64.7	63.1	64.4	64.5	62.8	63.6	64.5	64.0	65.1	65.4
17	Max....	67.0	65.2	65.1	67.1	65.2	65.0	65.6	64.9	64.3	66.0	64.5	64.4	65.6	64.9	65.1
	Min....	64.2	64.2	64.5	64.0	64.1	64.6	64.1	64.5	64.1	64.2	63.9	64.4	64.6	64.7	64.8
18	Max....	63.2	63.5	63.6	63.0	63.5	64.1	63.6	64.0	64.4	63.5	63.2	64.6	63.9	65.0	64.8
	Min....	59.4	62.0	63.0	58.5	61.7	63.5	60.6	63.3	63.7	60.6	62.6	63.8	62.5	64.2	64.6
19	Max....	66.3	63.7	62.6	66.7	63.9	62.6	65.4	62.4	63.5	65.1	62.0	63.5	63.8	64.1	64.5
	Min....	57.6	59.6	61.0	55.0	59.3	61.5	58.2	61.4	62.5	59.2	60.5	62.4	59.3	63.0	63.8
20	Max....	64.9	63.0	62.9	65.3	63.1	62.9	63.0	62.7	62.7	63.2	62.2	63.0	63.3	63.5	63.8
	Min....	59.9	61.3	62.3	59.3	61.2	62.6	60.1	62.2	62.3	60.1	61.6	62.5	61.5	62.8	63.2
22	Max....	55.6	56.7	57.5	55.5	56.7	58.6	55.5	58.0	60.7	55.6	56.9	60.2	56.5	61.3	63.0
	Min....	50.7	54.8	56.7	49.6	54.5	57.9	51.8	57.1	59.5	51.8	56.1	59.0	55.0	60.1	62.5
23	Max....	58.9	57.6	56.9	59.2	58.2	57.4	58.1	56.2	58.7	58.1	55.9	58.2	56.6	59.4	61.9
	Min....	47.9	52.5	54.7	47.4	52.0	56.0	48.9	54.9	57.7	48.4	54.0	57.2	52.3	58.0	61.0
24	Max....	67.6	62.0	59.5	69.5	63.0	59.5	64.7	58.0	57.8	65.0	58.5	57.7	59.9	58.0	60.2
	Min....	53.0	55.5	56.6	52.6	56.0	57.7	53.4	56.1	57.5	53.5	55.7	57.5	54.9	57.5	59.6
25	Max....	70.4	64.8	62.1	71.1	65.1	61.6	67.0	60.4	58.9	67.2	60.9	59.5	62.4	58.7	59.6
	Min....	56.4	59.5	59.9	55.5	59.7	60.3	57.1	58.8	58.9	57.0	58.5	59.4	57.8	58.4	59.5
26	Max....	61.6	63.0	63.1	60.7	62.9	63.0	61.4	62.0	60.6	61.4	61.9	61.4	61.5	59.9	59.9
	Min....	60.1	61.5	62.0	59.4	61.4	61.9	59.9	61.2	60.2	59.8	60.7	61.2	60.3	59.5	59.7
27	Max....	65.2	61.1	59.5	66.1	61.5	59.9	63.1	59.0	60.6	62.7	58.2	60.7	59.6	59.9	60.5
	Min....	50.3	56.1	57.6	49.0	55.5	58.5	51.7	57.5	59.3	51.5	56.6	59.2	55.0	58.9	60.1
29	Max....	64.2	62.0	61.2	64.4	62.1	61.1	63.0	60.4	59.5	63.0	60.0	59.8	61.4	59.1	59.9
	Min....	60.2	60.5	60.5	60.0	60.5	60.6	59.6	59.8	59.3	59.5	59.4	59.5	59.3	59.0	59.8
30	Max....	68.5	64.6	62.9	69.3	64.9	62.2	66.8	62.0	60.5	66.7	61.2	60.9	64.4	60.0	60.0
	Min....	61.9	61.7	61.7	61.6	61.6	61.5	61.5	61.1	60.0	61.5	60.7	60.5	61.4	59.8	59.9
Ave.	Max..	71.11	67.57	66.22	71.02	67.42	65.85	69.55	65.89	65.27	69.15	65.27	65.49	67.30	65.95	65.87
	Min..	61.41	64.05	64.74	60.40	63.70	64.85	62.25	64.78	64.66	61.72	63.78	64.81	64.04	65.30	65.51
	Range	9.70	3.52	1.48	10.62	3.72	1.00	7.30	1.11	0.61	7.43	1.49	0.68	3.26	0.65	0.36

TABLE 49.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TPYES OF SOIL, NOT COVERED WITH SAND, OCTOBER, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	66.4	64.1	63.1	66.2	64.1	62.7	65.6	62.6	62.6	65.8	61.9	61.9	64.2	61.3	61.0
	Min....	61.2	62.4	62.5	60.2	62.3	62.3	62.9	61.6	61.2	62.1	61.3	61.8	62.4	61.2	60.6
2	Max....	58.6	61.5	62.5	57.7	61.0	62.4	59.9	62.4	61.8	59.7	61.6	62.2	61.6	61.9	61.5
	Min....	57.1	59.5	60.8	56.1	59.1	61.2	58.0	61.0	61.4	58.1	59.8	61.6	59.9	61.5	61.4
3	Max....	63.0	61.0	59.9	62.6	61.1	59.7	62.1	59.5	60.6	62.1	59.1	60.5	61.4	61.0	61.5
	Min....	54.5	57.4	58.3	53.8	56.9	59.0	55.6	58.8	59.6	55.6	58.0	59.7	57.7	60.0	61.1
4	Max....	64.6	61.3	59.6	65.6	61.6	59.4	63.0	59.0	59.8	62.6	58.1	59.9	60.4	60.4	61.2
	Min....	52.1	56.7	57.9	50.4	56.0	58.3	53.6	57.9	59.0	53.5	57.0	58.9	56.1	59.4	60.7
6	Max....	69.9	64.4	62.0	70.7	64.9	61.4	67.0	61.0	59.7	67.0	59.8	60.2	63.8	59.9	60.3
	Min....	57.1	59.6	59.9	55.9	59.2	60.0	57.6	59.6	59.4	57.6	58.9	59.8	59.0	59.6	60.0
7	Max....	71.5	66.4	63.9	71.9	66.6	62.9	68.6	62.6	60.6	68.6	62.4	61.4	65.8	60.8	60.5
	Min....	60.7	62.4	62.1	59.6	62.0	61.9	61.1	61.6	60.5	61.0	60.6	61.3	61.8	60.7	60.3
8	Max....	67.6	65.7	64.6	67.5	65.6	64.0	67.1	63.9	62.0	67.2	63.8	62.7	66.0	62.1	61.4
	Min....	64.4	64.4	64.1	63.6	64.1	63.6	64.2	63.5	61.7	64.2	63.0	62.5	64.3	61.9	61.0
9	Max....	69.2	66.0	64.5	69.4	66.1	63.7	68.4	63.9	62.5	68.4	63.8	63.2	66.4	62.8	62.0
	Min....	61.5	63.0	63.3	60.2	62.6	62.9	62.5	63.3	62.3	62.3	62.4	62.9	63.2	62.6	61.9
10	Max....	70.0	66.8	65.0	71.0	67.1	64.3	68.7	64.6	62.7	68.5	64.1	63.5	67.1	63.3	62.6
	Min....	63.0	63.9	63.9	62.3	63.6	63.5	63.5	63.9	62.7	63.4	63.0	63.2	64.6	63.2	62.5
11	Max....	64.2	65.1	65.1	63.4	65.0	64.9	64.3	65.3	63.7	64.7	63.8	64.0	65.7	64.1	63.1
	Min....	61.6	63.7	64.0	60.4	63.6	64.0	62.5	64.1	63.4	62.0	62.5	63.6	64.3	64.0	63.0
13	Max....	56.6	55.8	56.1	56.4	55.9	57.5	56.1	56.9	59.9	55.5	55.2	59.4	55.2	60.9	62.5
	Min....	45.9	52.4	54.5	43.9	51.8	56.0	48.9	55.1	58.0	49.0	52.5	57.4	52.3	59.0	61.5
14	Max....	59.1	56.1	55.2	60.7	57.1	56.0	57.2	55.0	57.2	56.9	53.4	56.6	55.0	58.0	59.5
	Min....	47.5	52.1	53.6	47.0	51.9	54.9	49.0	53.9	56.1	48.9	52.0	55.7	51.9	56.7	58.6
15	Max....	59.6	57.1	56.4	60.6	57.7	56.9	57.9	55.4	56.3	57.9	54.1	56.2	55.9	56.6	59.1
	Min....	51.0	54.2	55.7	50.3	54.4	56.1	51.8	54.6	56.0	51.6	53.1	55.9	53.4	56.1	57.4
16	Max....	55.7	56.0	56.8	55.8	56.3	57.5	54.9	56.1	56.4	55.1	55.0	56.5	55.1	56.4	57.1
	Min....	53.1	55.2	56.1	52.6	55.3	56.9	53.4	55.6	56.3	53.5	53.9	56.4	54.6	56.3	56.8
17	Max....	57.7	56.5	56.4	57.8	56.6	56.8	56.8	55.7	56.3	57.1	54.4	56.3	56.0	56.1	59.2
	Min....	53.8	55.0	55.8	53.1	55.1	56.5	53.8	55.3	56.0	54.0	53.7	56.1	54.4	55.8	57.2
18	Max....	52.6	54.5	56.1	51.6	54.4	57.0	53.0	56.1	56.5	53.0	55.1	56.9	54.8	56.3	57.5
	Min....	51.0	53.5	55.0	49.7	53.2	55.7	51.5	54.8	56.1	51.6	52.9	56.1	53.6	56.1	57.4
20	Max....	47.5	49.0	50.4	47.0	49.1	51.8	47.1	50.5	53.4	47.3	49.2	53.0	48.6	53.4	56.1
	Min....	44.0	47.7	49.8	43.6	47.4	51.1	44.9	49.7	52.6	45.1	47.1	52.0	47.2	52.5	55.5
21	Max....	47.8	48.7	49.6	47.8	48.9	50.9	46.9	49.1	51.9	46.9	48.4	51.5	47.9	52.0	55.2
	Min....	43.6	47.1	48.6	43.5	47.1	50.1	43.9	48.4	51.2	44.1	46.1	50.9	46.4	51.2	54.4
22	Max....	44.1	46.4	48.4	43.9	46.4	50.0	43.5	48.1	50.9	43.5	47.4	50.6	45.9	50.8	53.8
	Min....	41.5	45.5	47.6	40.0	45.4	49.1	41.8	47.0	50.1	43.0	44.9	49.6	45.1	50.0	53.2
23	Max....	41.5	44.0	46.5	40.2	43.8	48.1	40.8	45.8	49.3	41.4	44.9	48.7	43.4	49.3	52.4
	Min....	38.9	42.9	45.2	38.8	42.8	46.5	39.5	44.2	48.1	39.7	43.1	47.8	41.7	48.2	52.1
24	Max....	47.8	46.5	46.2	47.6	46.7	46.9	46.5	47.1	47.5	47.0	43.6	47.2	43.8	47.0	50.9
	Min....	41.4	43.1	44.9	40.6	43.3	45.9	40.9	44.0	46.9	41.3	42.0	46.7	41.0	45.9	49.8
25	Max....	46.0	46.2	46.6	45.6	46.4	47.5	45.6	45.7	47.5	45.9	45.4	47.5	43.7	46.2	49.4
	Min....	39.9	44.3	45.6	38.1	44.0	46.8	40.8	44.9	47.3	41.1	42.9	47.2	42.1	45.8	49.0
27	Max....	45.0	46.1	47.2	44.9	46.3	48.1	44.4	46.5	47.6	44.8	45.2	47.7	44.4	45.9	48.5
	Min....	43.9	45.9	46.8	43.3	45.9	47.9	44.0	46.0	47.5	44.4	44.2	47.5	44.0	44.9	48.4
28	Max....	44.9	45.8	46.6	44.4	45.8	47.6	44.3	45.6	47.2	44.8	43.5	47.6	44.2	46.1	48.4
	Min....	43.4	45.0	46.1	42.9	45.1	47.3	42.9	45.4	47.2	43.5	43.1	47.3	43.6	45.9	48.3
29	Max....	45.1	45.9	46.6	44.6	46.1	47.5	44.9	45.7	47.3	45.3	44.8	47.4	44.2	45.9	48.3
	Min....	43.4	45.0	46.1	42.5	45.1	47.1	43.0	45.5	47.1	43.5	43.1	47.2	43.4	45.7	48.1
30	Max....	42.2	44.1	45.9	41.0	44.0	47.1	41.7	45.5	47.3	42.4	44.6	47.4	43.1	45.8	48.1
	Min....	39.9	42.7	44.9	38.6	42.5	46.0	39.5	44.0	46.6	40.6	42.9	46.5	41.6	45.5	48.0
31	Max....	40.7	42.8	44.0	40.9	42.7	45.2	40.9	43.5	46.0	40.9	42.5	46.1	40.8	45.0	47.9
	Min....	38.6	41.6	43.5	38.8	41.4	44.7	38.9	42.9	45.6	39.4	40.9	45.4	40.0	44.4	47.5
Ave.	Max..	55.51	54.96	55.01	55.44	55.09	55.47	54.71	54.56	55.35	54.83	53.52	55.41	54.24	55.16	56.63
	Min..	50.15	52.82	53.94	49.25	52.63	54.64	50.74	53.58	54.81	50.89	52.03	54.85	52.21	54.60	56.14
	Range	5.36	2.14	1.07	6.19	2.46	0.83	3.97	0.98	0.54	3.94	1.49	0.56	2.03	0.56	0.49

TABLE 50.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, NOVEMBER, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	41.9	42.4	42.9	41.5	42.6	44.4	40.7	42.5	45.4	40.7	41.2	45.0	40.2	44.1	47.4
	Min....	36.6	40.0	42.1	35.9	40.0	43.8	37.1	41.8	44.7	37.9	40.1	44.2	39.2	43.5	46.9
3	Max....	45.1	44.4	44.4	45.4	44.7	45.2	43.2	42.9	44.1	43.9	41.0	44.1	41.6	42.7	45.9
	Min....	41.3	42.4	43.3	41.0	42.8	44.5	40.3	42.3	44.0	40.5	40.0	43.8	40.0	42.6	45.6
4	Max....	42.4	43.2	44.2	42.1	43.5	45.5	41.6	43.4	44.7	41.9	42.2	44.9	41.5	43.2	45.7
	Min....	38.9	42.0	43.5	38.2	42.1	44.7	39.5	42.8	44.6	40.0	40.5	44.6	40.7	43.0	45.4
5	Max....	43.4	42.6	42.9	43.9	43.1	44.4	41.8	42.3	44.7	41.8	41.4	44.6	40.0	43.1	45.7
	Min....	36.4	39.8	41.7	35.6	39.9	43.4	37.0	41.5	43.9	37.2	38.6	43.6	39.4	42.8	45.4
6	Max....	43.6	42.4	42.4	44.2	43.0	43.9	42.1	41.9	44.1	41.9	40.5	43.9	39.5	42.9	45.6
	Min...	36.4	39.6	41.4	35.7	39.8	43.1	37.2	41.2	43.5	37.1	38.4	43.1	38.9	42.2	45.1
7	Max...	49.2	46.3	45.1	50.1	46.6	45.5	47.0	43.7	44.0	47.5	43.7	44.0	42.7	42.4	45.0
	Min....	42.1	42.8	43.3	42.0	43.0	44.4	41.2	42.3	43.5	41.5	39.9	43.5	40.2	42.1	44.8
8	Max .	47.0	47.3	47.1	46.9	47.5	47.4	46.6	46.0	45.7	47.0	45.7	46.2	44.9	43.9	45.2
	Min ..	43.3	45.8	46.5	42.4	45.8	47.2	43.7	45.7	44.9	44.0	45.0	45.5	44.2	43.0	44.9
10	Max ..	35.7	39.0	41.2	34.7	39.0	42.8	36.3	41.2	44.4	36.1	40.6	44.0	39.4	43.5	46.0
	Min ...	35.5	38.4	40.4	34.5	38.3	42.1	35.9	40.4	43.6	35.6	39.6	42.9	38.6	43.0	45.9
11	Max ..	35.9	38.4	40.0	34.9	38.1	41.5	35.6	39.7	42.8	35.4	39.0	42.1	38.0	42.4	45.5
	Min....	35.5	38.0	39.7	34.8	38.0	41.1	35.3	39.2	42.2	35.3	38.8	41.5	37.5	41.8	45.0
12	Max....	35.5	37.9	39.5	35.1	38.0	41.1	35.5	39.0	41.9	36.3	38.6	41.2	37.3	41.4	44.8
	Min....	35.0	37.3	39.0	34.5	37.4	40.6	34.6	38.1	41.1	34.7	37.7	40.6	36.6	40.8	44.1
13	Max....	39.9	39.8	38.8	41.2	40.0	40.4	42.9	40.1	40.9	43.9	40.5	41.2	38.6	40.5	43.6
	Min.....	34.6	36.9	38.1	34.6	37.3	39.9	36.7	38.1	40.7	38.5	38.1	40.8	36.5	40.0	43.3
14	Max....	39.2	39.5	39.4	40.6	41.8	42.1	42.4	41.8	42.3	42.9	42.1	42.8	40.5	40.6	43.0
	Min....	35.4	37.2	38.4	37.9	40.1	41.8	40.4	41.3	42.0	41.0	41.2	42.6	39.4	40.5	42.9
15	Max....	35.5	37.9	39.4	35.5	39.1	41.9	37.6	41.5	42.8	38.0	41.4	43.1	39.3	41.1	43.2
	Min....	35.2	37.4	38.7	35.4	38.4	41.1	36.8	40.5	42.5	37.2	40.2	42.6	38.2	41.0	43.1
17	Max...	40.0	39.3	39.4	40.3	39.9	40.9	39.4	39.6	41.5	39.7	39.5	41.6	37.3	40.4	43.1
	Min....	35.4	37.4	38.6	34.8	37.8	40.6	36.2	39.3	41.1	36.5	38.9	41.1	37.0	40.0	42.7
18	Max...	45.1	42.9	42.0	45.7	43.5	42.8	43.8	41.5	41.8	44.5	41.4	42.0	40.4	40.1	42.6
	Min....	40.8	40.3	40.4	41.2	40.7	41.6	40.0	40.4	41.4	40.6	40.0	41.4	38.2	39.9	42.4
19	Max...	53.1	49.2	47.1	53.6	49.6	46.9	51.6	46.3	43.8	52.1	46.4	44.8	47.1	42.0	42.8
	Min.. .	49.5	45.9	44.4	50.1	46.5	44.7	49.1	44.7	42.7	48.5	44.0	43.4	43.6	40.7	42.5
20	Max ..	54.0	51.3	49.9	54.3	51.4	49.4	52.9	49.2	46.5	53.4	49.1	47.9	50.0	44.9	44.2
	Min	52.4	50.4	49.0	52.5	50.7	48.7	51.6	48.2	45.5	52.3	48.4	46.7	49.0	43.8	43.4
21	Max ..	55.8	53.4	51.7	56.2	53.5	51.1	55.0	51.2	48.5	55.5	51.7	49.7	52.4	47.1	46.2
	Min...	53.5	52.1	50.9	53.2	52.1	50.5	53.0	50.4	47.8	53.5	50.3	49.1	51.2	46.2	45.3
22	Max....	57.0	54.1	52.6	57.4	54.1	52.0	56.1	52.5	50.0	56.6	52.5	51.1	53.7	49.1	48.0
	Min....	53.3	52.8	52.0	53.0	52.8	51.5	53.4	51.9	49.5	53.6	52.0	50.8	52.4	48.3	47.3
24	Max ...	42.5	45.1	47.4	41.4	44.7	48.3	42.7	48.1	49.9	42.8	47.6	50.0	46.8	50.0	50.2
	Min...	40.2	43.8	45.9	38.5	43.7	46.6	42.0	46.4	48.7	42.1	45.9	49.1	45.6	49.1	50.1
25	Max..	39.9	41.6	44.1	39.5	41.5	45.5	39.3	44.8	47.5	39.9	44.0	47.1	43.8	48.2	50.2
	Min...	37.3	40.8	42.3	36.2	40.5	44.1	37.8	43.1	46.1	37.9	42.5	45.6	42.1	47.0	49.4
26	Max....	42.0	42.8	43.4	41.5	42.9	44.4	41.6	43.0	45.2	42.0	43.0	44.9	42.5	46.0	48.6
	Min....	40.4	41.8	43.0	40.0	42.0	44.2	40.3	42.9	44.8	40.7	42.6	44.6	42.0	45.4	48.0
27	Max....	40.6	42.1	43.0	40.2	42.1	44.4	40.6	42.9	44.7	41.2	42.7	44.6	42.0	44.9	47.4
	Min...	39.7	41.8	43.0	39.0	41.8	44.0	39.9	42.6	44.4	40.4	42.5	44.2	41.7	44.5	46.9
28	Max....	42.4	42.5	42.9	42.3	42.6	43.9	41.6	42.5	44.1	42.4	42.5	44.1	41.8	44.1	46.4
	Min....	39.9	41.5	42.6	39.4	41.6	43.7	39.7	42.2	43.9	40.5	42.1	43.9	41.4	43.8	46.1
29	Max .	44.0	43.9	44.1	43.9	44.1	44.9	43.4	43.4	44.1	43.9	43.7	44.4	42.7	43.7	45.6
	Min....	42.9	43.2	43.6	42.6	43.4	44.5	42.3	43.1	43.9	43.0	43.1	44.1	42.4	43.6	45.5
Ave.	Max.	43.63	43.57	43.80	43.70	43.88	44.82	43.25	43.64	44.62	43.65	43.28	44.77	42.56	43.69	45.68
	Min..	40.46	42.38	42.87	40.12	42.26	44.10	40.84	42.82	44.04	41.20	42.02	44.13	41.44	43.14	45.28
	Range	3.17	1.19	0.93	3.58	1.62	0.72	2.41	0.82	0.58	2.45	1.26	0.64	1.12	0.55	0.40

BEGINNING WITH THIRD YEAR.

TABLE 51.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, DECEMBER, 1913.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	50.9	49.6	48.9	50.7	49.7	48.6	50.0	48.1	46.6	50.6	48.5	47.4	48.4	45.5	45.9
	Min....	50.4	49.1	48.2	50.3	49.3	48.1	49.5	47.4	45.9	50.1	47.7	46.6	47.0	44.9	45.6
2	Max....	51.5	50.3	49.6	51.9	50.3	49.6	50.7	49.1	47.6	51.2	49.5	48.5	49.5	46.9	46.8
	Min....	49.9	49.5	49.1	49.5	48.9	49.0	49.5	48.6	47.4	50.0	48.9	48.1	48.7	46.4	46.3
3	Max....	47.9	49.2	49.5	47.2	49.1	49.5	48.4	49.3	48.4	48.8	49.4	49.0	48.9	47.8	48.0
	Min....	46.6	48.3	48.6	46.0	48.1	48.9	47.4	48.6	48.3	47.8	48.6	48.9	48.4	47.5	47.4
4	Max...	44.9	45.5	46.3	44.5	45.4	47.1	44.6	46.9	48.0	44.9	47.4	48.3	45.5	47.7	48.4
	Min....	41.3	44.1	45.5	40.4	43.9	46.4	41.9	45.8	47.1	42.4	45.6	47.1	44.8	47.2	48.2
5	Max....	43.5	44.3	45.0	43.3	44.3	46.0	43.4	4.50	46.7	43.3	44.6	46.7	43.9	46.6	48.4
	Min....	40.1	43.1	44.4	39.2	43.0	45.4	40.7	44.4	46.0	41.1	44.1	45.9	43.3	46.3	48.0
6	Max ..	42.4	43.0	44.0	42.0	43.0	45.1	41.8	43.9	45.7	42.2	43.4	45.5	42.8	45.7	47.9
	Min....	38.9	41.9	43.5	37.6	41.8	44.5	39.4	43.2	45.1	39.5	42.7	44.8	41.4	45.2	47.3
8	Max....	35.0	39.0	41.3	34.9	39.5	43.1	36.5	41.5	44.4	36.5	41.1	44.0	40.5	44.3	47.3
	Min....	34.4	37.9	40.1	34.5	38.4	42.1	35.8	40.4	43.4	35.7	39.8	42.8	39.4	43.6	46.4
9	Max....	33.4	37.1	39.3	33.1	37.6	41.5	34.9	39.7	42.7	34.5	39.4	42.0	38.4	42.9	45.6
	Min....	33.0	36.4	38.5	32.9	36.9	40.6	34.4	38.7	42.0	34.0	38.0	41.2	37.4	42.0	45.2
10	Max....	33.6	36.4	38.1	33.5	36.8	40.2	34.3	38.4	41.4	34.2	37.5	40.5	36.8	41.5	44.6
	Min....	33.5	36.2	37.9	33.3	36.8	40.0	34.1	38.0	41.0	34.1	37.3	40.2	36.1	40.9	44.1
11	Max...	33.6	36.4	38.0	33.4	37.0	39.9	34.2	37.9	40.8	34.4	37.4	40.0	36.5	40.4	43.5
	Min....	33.1	35.9	37.4	32.8	36.3	39.5	33.7	37.3	4.02	33.9	36.8	39.6	35.9	39.9	43.0
12	Max...	33.4	36.8	37.4	33.4	36.3	39.5	33.7	37.2	40.0	33.8	36.7	39.4	35.7	39.5	42.8
	Min....	33.1	35.5	37.1	32.7	36.0	38.9	33.4	36.8	39.6	33.5	36.4	38.9	35.3	38.9	42.0
13	Max....	37.2	37.0	37.5	37.4	37.6	39.1	33.6	36.9	39.4	34.1	36.5	38.9	35.2	38.8	42.1
	Min....	33.8	35.9	37.1	33.6	36.4	39.0	33.5	36.6	39.1	34.0	36.4	38.7	34.2	38.4	41.4
15	Max....	34.1	36.6	37.9	33.5	36.8	39.4	34.4	37.2	39.4	34.9	37.1	39.2	35.0	38.0	40.9
	Min....	33.7	36.1	37.4	33.1	36.2	38.9	34.0	37.0	39.1	34.5	36.9	38.8	34.0	37.7	40.5
16	Max....	37.8	38.0	38.2	37.6	38.3	39.4	36.6	37.2	39.0	37.3	37.3	38.6	33.9	37.6	40.5
	Min....	35.0	36.4	37.3	34.8	36.5	38.7	34.0	36.8	38.9	34.5	36.6	38.7	33.8	37.5	40.2
17	Max....	36.1	37.3	38.1	35.7	37.6	39.6	35.7	37.5	39.3	37.5	37.7	39.2	34.7	37.5	40.3
	Min....	35.2	36.9	38.0	34.6	37.1	39.2	34.8	37.3	39.0	35.5	37.4	39.0	33.8	37.4	40.0
18	Max....	34.4	36.5	37.8	33.7	36.6	39.0	34.6	37.4	39.3	35.1	37.4	39.1	34.6	37.4	40.0
	Min....	34.1	36.4	37.6	33.6	36.5	38.7	34.3	37.2	39.1	34.9	37.2	39.0	34.5	37.2	39.9
19	Max....	33.3	35.9	37.2	32.5	36.0	38.6	33.9	36.9	38.9	34.3	37.0	38.8	34.5	37.4	40.1
	Min....	33.1	35.4	36.7	32.4	35.4	38.2	33.5	36.6	38.6	34.0	36.5	38.5	33.4	37.1	39.8
20	Max...	33.1	35.2	36.6	32.6	35.5	38.2	33.4	36.4	38.7	33.8	36.3	38.4	34.4	37.1	39.8
	Min....	33.1	35.1	36.5	32.4	35.3	37.9	33.4	36.3	38.4	33.6	36.1	38.1	34.3	37.0	39.7
22	Max....	32.2	34.4	35.9	31.4	34.4	37.5	32.8	35.9	38.1	32.6	35.5	37.9	34.1	37.1	39.6
	Min....	30.1	33.9	35.2	26.5	33.9	36.9	32.3	35.5	37.8	32.2	35.0	37.2	33.7	36.6	39.2
23	Max....	32.3	33.9	35.3	31.8	33.9	36.8	32.3	35.1	37.5	32.4	34.8	37.1	33.5	36.5	39.0
	Min....	31.5	33.6	35.0	30.5	33.6	36.6	32.1	35.0	37.3	32.2	34.7	36.8	33.4	36.4	38.9
24	Max....	32.3	33.8	35.1	32.1	33.9	36.6	32.2	35.1	37.1	32.5	34.6	36.6	33.3	36.2	38.7
	Min....	32.2	33.6	34.9	32.0	33.8	36.4	32.1	34.8	37.0	32.4	34.4	36.4	32.3	35.8	38.2
26	Max....	32.8	34.3	35.3	32.4	34.7	36.8	32.5	34.9	36.9	32.9	34.8	36.7	33.1	35.8	38.4
	Min....	32.7	34.1	35.3	32.3	34.5	36.8	32.4	34.8	36.5	32.7	34.7	36.5	32.5	35.7	38.1
27	Max....	32.7	34.7	35.6	32.0	34.9	37.0	32.6	35.3	37.1	33.2	35.1	36.8	33.6	36.0	38.5
	Min....	32.0	33.6	34.7	31.0	33.7	36.2	32.0	34.4	36.3	32.3	34.2	36.1	32.7	35.1	38.2
29	Max....	32.3	33.8	34.8	32.0	34.0	37.0	32.1	34.3	36.2	32.4	34.2	35.9	32.5	34.9	37.3
	Min....	32.2	33.7	34.7	31.9	33.9	36.0	32.0	34.2	36.0	32.3	34.1	35.8	31.6	34.7	37.2
30	Max....	32.3	34.0	34.7	32.1	34.1	36.9	32.1	34.1	36.3	32.5	34.1	35.9	32.6	34.6	37.1
	Min....	32.0	33.5	34.3	31.6	33.6	35.8	31.7	33.9	35.6	32.2	33.9	35.6	32.3	34.3	36.8
31	Max...	32.4	33.8	34.9	32.3	34.2	36.2	32.1	34.2	36.1	32.6	34.4	36.0	32.7	34.8	37.3
	Min...	32.3	33.7	34.7	32.1	34.0	36.1	31.8	34.0	36.0	32.5	34.1	35.8	30.3	34.6	36.7
Ave.	Max	36.75	38.34	39.32	36.42	38.52	40.70	36.67	39.05	40.83	37.02	38.91	40.64	37.48	39.94	42.26
	Min	35.67	37.68	38.83	35.06	37.84	40.18	35.91	38.60	40.41	36.23	38.39	40.20	36.71	39.55	41.86
	Range	1.08	0.66	0.49	1.36	0.68	0.52	0.76	0.45	0.42	0.79	0.52	0.44	0.77	0.39	0.40

TABLE 52.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, JANUARY, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	**Max**	32.5	34.1	34.8	32.3	34.2	36.1	32.1	34.2	36.1	32.6	34.3	35.8	32.3	34.8	37.1
	Min	32.3	33.8	34.7	32.1	34.0	36.0	32.0	34.0	36.0	32.5	34.1	35.6	31.6	34.4	36.8
2	**Max**	32.5	34.0	34.9	32.2	34.2	36.1	32.1	34.3	36.0	32.7	34.3	35.8	32.6	34.7	37.2
	Min	32.4	33.8	34.8	32.1	34.1	35.8	32.1	34.1	35.8	32.6	34.1	35.7	32.4	34.5	37.0
3	**Max**	32.7	34.1	35.1	32.6	34.3	36.1	32.3	34.3	36.0	32.8	34.5	35.9	32.7	34.7	37.1
	Min	32.5	34.0	34.8	32.3	34.2	36.0	32.1	34.1	35.9	32.6	34.3	35.7	32.3	34.5	36.9
5	**Max**	33.1	34.4	35.1	32.9	34.6	36.3	32.4	34.4	36.0	33.1	34.6	36.0	32.9	34.8	37.1
	Min	32.9	34.3	35.0	32.7	34.5	36.2	32.3	34.3	35.9	33.1	34.4	35.9	32.8	34.6	37.0
6	**Max**	33.3	34.5	35.1	33.0	34.6	36.3	32.4	34.4	36.0	33.2	34.6	36.0	32.9	34.8	37.1
	Min	33.2	34.4	35.1	33.0	34.5	36.2	32.3	34.3	35.9	33.1	34.5	35.9	32.4	34.6	36.9
7	**Max**	33.2	34.4	35.4	33.1	34.6	36.3	32.4	34.4	35.9	33.2	34.7	36.1	32.8	34.7	36.9
	Min	33.2	34.4	35.1	33.0	34.6	36.2	32.3	34.3	35.9	33.2	34.5	35.9	32.5	34.6	36.8
8	**Max**	33.4	34.6	35.2	33.1	34.7	36.4	32.4	34.4	36.0	33.4	34.7	35.9	32.8	34.6	36.9
	Min	33.2	34.4	35.1	32.9	34.6	36.2	32.3	34.2	35.9	33.3	34.5	35.9	32.7	34.5	36.8
9	**Max**	33.4	34.6	35.2	33.1	34.7	36.3	32.5	34.4	35.9	33.4	34.7	36.1	32.7	34.7	36.9
	Min	33.3	34.4	35.1	33.0	34.6	36.2	32.4	34.3	35.9	33.4	34.6	36.0	32.6	34.5	36.8
10	**Max**	33.5	34.6	35.3	33.3	34.7	36.3	32.7	34.5	36.0	33.6	34.9	36.2	32.9	34.7	36.9
	Min	33.4	34.5	35.2	33.1	34.6	36.2	32.5	34.4	36.0	33.5	34.9	36.1	32.7	34.6	36.8
12	**Max**	33.5	34.7	35.5	33.3	34.7	36.4	32.9	34.8	36.2	33.9	35.3	36.4	33.1	34.9	37.0
	Min	33.4	34.7	35.4	33.1	34.6	36.2	32.8	34.6	36.1	33.9	35.1	36.3	33.0	34.7	37.0
13	**Max**	33.9	35.1	35.8	33.4	35.0	36.6	33.3	35.1	36.5	34.2	35.6	36.7	33.4	35.2	37.4
	Min	33.4	34.5	35.3	32.9	34.5	36.1	32.9	34.8	36.1	33.7	35.0	36.3	33.0	34.7	36.9
14	**Max**	33.8	35.0	35.8	33.3	34.9	36.7	33.4	35.3	36.7	34.2	35.5	36.8	33.5	35.2	37.4
	Min	33.6	34.8	35.5	33.1	34.7	36.4	33.1	34.9	36.4	33.9	35.3	36.4	33.3	35.0	37.2
15	**Max**	33.7	34.7	35.5	33.1	34.8	36.4	33.1	34.9	36.4	34.0	35.3	36.4	33.4	35.1	37.1
	Min	33.4	34.7	35.4	33.1	34.6	36.3	33.0	34.9	36.4	33.9	35.2	36.4	33.3	34.9	37.1
16	**Max**	33.8	34.9	35.6	33.2	34.8	36.4	33.3	35.0	36.4	34.0	35.2	36.5	33.4	35.0	37.1
	Min	33.6	34.7	35.5	33.2	34.6	36.3	33.0	34.9	36.3	33.9	35.1	36.4	33.3	34.9	36.9
17	**Max**	33.7	35.0	35.6	33.4	34.8	36.4	33.3	35.0	36.4	34.1	35.3	36.5	33.4	35.1	37.2
	Min	33.7	34.9	35.6	33.3	34.7	36.4	33.1	34.9	36.3	34.0	35.2	36.4	33.3	34.9	37.1
19	**Max**	33.9	34.9	35.6	33.4	34.9	36.4	33.3	35.0	36.4	34.1	35.4	36.5	33.4	35.0	37.1
	Min	33.7	34.9	35.5	33.4	34.9	36.4	33.2	34.9	36.3	34.1	35.3	36.4	33.3	34.9	37.0
20	**Max**	33.8	34.9	35.6	33.4	34.9	36.4	33.3	35.0	36.4	34.1	35.4	36.5	33.4	35.0	37.1
	Min	33.7	34.9	35.4	33.3	34.8	36.4	33.2	34.9	36.3	34.0	35.3	36.4	33.3	34.9	36.9
21	**Max**	33.9	35.0	35.6	33.6	34.9	36.5	33.3	35.1	36.4	34.2	35.4	36.5	33.4	35.1	37.1
	Min	33.8	34.9	35.6	33.5	34.9	36.4	33.2	35.0	36.3	34.1	35.4	36.4	33.4	34.9	37.1
22	**Max**	34.0	35.0	35.7	33.6	35.1	36.4	33.4	35.0	36.4	34.3	35.5	36.6	33.5	35.1	37.2
	Min	33.9	34.9	35.5	33.5	34.9	36.4	33.3	35.0	36.3	34.1	35.4	36.4	33.4	34.9	37.0
23	**Max**	33.9	34.9	35.6	33.6	35.0	36.4	33.4	34.9	36.3	34.2	35.5	36.5	33.4	34.9	37.0
	Min	33.9	34.8	35.4	33.5	34.9	36.3	33.2	34.9	36.1	34.1	35.2	36.3	33.3	34.8	36.9
24	**Max**	34.0	34.9	35.6	33.6	34.9	36.4	33.5	35.0	36.4	34.2	35.4	36.5	33.5	35.0	37.1
	Min	33.9	34.7	35.4	33.4	34.7	36.2	33.4	35.0	36.3	34.1	35.1	36.4	33.4	34.9	37.0
26	**Max**	33.8	34.9	35.7	33.3	34.9	36.5	33.4	35.1	36.4	34.0	35.4	36.4	33.4	34.9	36.9
	Min	33.6	34.9	35.6	33.1	34.7	36.2	33.3	35.0	36.3	34.0	35.2	36.3	33.4	34.7	36.7
27	**Max**	33.6	34.8	35.5	33.3	34.8	36.3	33.3	35.0	36.3	33.9	35.3	36.3	33.3	34.7	36.6
	Min	33.4	34.5	35.2	33.1	34.5	36.2	33.3	34.9	36.2	33.8	34.9	36.0	33.3	34.6	36.6
28	**Max**	33.7	34.7	35.5	33.4	34.7	36.2	33.4	34.9	36.1	34.0	35.1	36.1	33.4	34.7	36.6
	Min	33.6	34.6	35.2	33.2	34.6	36.2	33.3	34.6	35.7	33.9	34.9	36.0	33.2	34.6	36.6
29	**Max**	41.5	39.7	38.1	42.3	39.7	37.6	38.3	35.6	35.8	41.1	37.7	36.6	33.4	34.4	36.4
	Min	37.4	35.5	35.5	37.5	35.5	36.1	33.1	34.5	35.6	36.2	35.1	35.9	33.3	34.4	36.1
30	**Max**	35.0	36.9	37.5	34.4	36.9	38.0	34.9	36.7	36.9	35.9	37.6	37.8	33.4	34.6	36.3
	Min	34.0	35.6	36.7	33.6	35.8	37.4	34.0	36.1	36.8	34.7	36.6	37.5	33.3	34.4	36.2
31	**Max**	33.4	35.1	36.1	33.0	35.1	37.0	33.5	35.7	36.9	33.9	35.9	37.1	33.4	34.6	36.5
	Min	33.4	34.9	35.8	32.9	34.9	36.7	33.4	35.5	36.8	33.8	35.6	36.9	33.3	34.5	36.3
Ave.	**Max**	33.87	34.98	35.63	33.56	35.01	36.49	33.24	34.90	36.27	34.09	35.30	36.39	33.17	34.85	36.97
	Min	33.55	34.64	35.35	33.22	34.69	36.28	32.89	34.71	36.14	33.76	34.99	36.21	33.00	34.68	36.83
	Range	0.32	0.34	0.28	0.34	0.32	0.21	0.35	0.19	0.13	0.33	0.31	0.18	0.17	0.17	0.14

TABLE 53.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, FEBRUARY, 1914.

Date—Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2 Max....	33.6	35.0	35.8	33.4	35.0	36.6	33.4	35.4	36.7	34.0	35.4	36.6	33.6	35.0	37.1
Min....	33.5	34.6	35.4	33.1	34.8	36.4	33.2	35.0	36.3	33.8	35.1	36.2	33.4	34.8	36.6
3 Max	33.4	34.6	35.4	33.1	34.7	36.2	33.1	34.9	36.2	33.7	35.1	36.3	33.4	34.9	36.8
Min....	33.4	34.5	35.2	33.0	34.5	36.1	33.0	34.7	36.1	33.5	34.9	36.0	33.3	34.6	36.5
4 Max...	33.6	34.8	35.5	33.4	34.8	36.4	33.4	35.0	36.3	33.9	35.1	36.4	33.4	34.8	36.8
Min....	33.6	34.7	35.4	33.3	34.7	36.2	33.3	34.9	36.1	33.8	35.0	36.2	33.4	34.8	36.6
5 Max....	33.9	35.0	35.6	33.6	35.0	36.6	33.5	35.3	36.4	34.1	35.4	36.4	33.7	35.0	37.0
Min....	33.6	34.6	35.4	33.2	34.7	36.2	33.3	34.9	36.1	33.8	35.0	36.1	33.4	34.7	36.6
6 Max...	33.8	34.9	35.5	33.3	34.8	36.4	33.4	35.0	36.3	33.9	35.1	36.2	33.4	34.9	36.8
Min....	33.6	34.7	35.4	33.2	34.6	36.2	33.2	34.9	36.1	33.9	35 0	36.1	33.4	34.8	36.7
7 Max....	33.8	34.9	35.5	33.4	34.8	36.2	33.4	35.0	36.1	34.0	35.1	36.2	33.5	35.0	36.6
Min....	33.6	34.7	35.4	33.1	34.6	36.1	33.2	34.9	36.0	33.9	34.9	36.1	33.4	34.7	36.5
9 Max...	34.1	35.2	35.9	33.5	35.0	36.5	33.6	35.2	36.4	34.3	35.5	36.5	33.9	35.2	37.1
Min..	33.8	34.9	35.5	33.1	34.7	36.2	33.3	35.0	36.1	33.9	35.1	36.1	33.5	34.9	36.7
10 Max...	33.9	35.0	35.7	33.3	34.8	36.4	33.4	35.1	36.2	34.1	35.3	36.4	33.7	35.0	36.9
Min....	33.6	34.7	35.4	32.9	34.4	36.0	33.2	34.8	35.9	33.7	34.9	36.0	33.4	34.7	36.6
11 Max	33.8	34.9	35.6	33.1	34.7	36.4	33.4	35.1	36.3	34.0	35.2	36.4	33.7	35.0	36.9
Min....	33.5	34.7	35.3	32.7	34.5	36.1	33.2	34.8	36.1	33.8	35.0	36.0	33.5	34.8	36.6
12 Max..	34.0	35.3	35.8	33.4	34.9	36.4	33.7	35.4	36.4	34.4	35.5	36.6	34.0	35.4	37.1
Min....	33.5	34.7	35.3	32.6	34.5	36.0	33.2	34.9	36.0	33.9	35.0	36.1	33.5	34.9	36.7
13 Max	33.8	34.9	35.5	32.6	34.7	36.2	33.4	35.2	36.4	34.1	35.3	36.4	33.9	35.2	37.0
Min....	33.4	34.6	35.2	32.2	34.3	36.1	33.2	34.9	36.1	33.7	34.9	36.0	33.6	34.9	36.6
14 Max....	33.4	34.6	35.5	32.4	34.5	36.1	33.4	35.1	36.2	33.9	35.0	36.1	33.7	35.1	36.9
Min....	33.1	34.2	34.9	31.9	34.0	35.6	32.8	34.5	35.7	33.4	34.6	35.6	33.4	34.6	36.5
16 Max...	33.3	34.4	35.1	32.5	34.3	35.9	33.0	34.8	35.9	33.7	34.9	36.0	33.5	34.9	36.7
Min....	33.0	34.2	34.9	32.2	34.0	35.5	32.8	34.4	35.7	33.4	34.6	35.5	33.3	34.6	36.4
17 Max....	33.4	34.5	35.0	32.4	34.1	35.8	33.0	34.7	35.9	33.6	34.9	35.8	33.5	34.8	36.6
Min....	33.2	34.3	34.9	32.3	34.0	35.5	32.8	34.5	35.6	33.4	34.7	35.6	33.4	34.6	36.4
18 Max...	33.4	34.4	35.1	32.5	34.1	35.7	33.0	34.6	35.9	33.6	34.8	35.8	33.4	34.7	36.6
Min....	33.2	34.2	34.7	32.3	34.0	35.5	32.8	34.4	35.5	33.4	34.6	35.6	33.2	34.5	36.4
19 Max...	33.4	34.4	35.0	32.5	34.1	35.6	33.0	34.5	35.7	33.6	34.7	35.7	33.4	34.6	36.4
Min....	33.2	34.2	34.8	32.4	34.0	35.5	32.8	34.4	35.5	33.5	34.6	35.6	33.3	34.5	36.3
20 Max....	33.6	34.6	35.4	33.0	34.5	36.0	33.4	34.9	36.0	34.0	35.1	36.0	33.6	34.9	36.6
Min....	33.2	34.2	34.9	32.4	34.1	35.5	32.9	34.4	35.5	33.5	34.6	35.5	33.3	34.5	36.3
21 Max....	33.6	34.6	35.3	33.0	34.5	36.0	33.4	34.9	36.0	34.0	35.0	36.0	33.7	34.9	36.7
Min....	33.3	34.3	34.8	32.5	34.1	35.6	32.9	34.4	35.5	33.5	34.6	35.6	33.2	34.5	36.3
23 Max...	33.6	34.7	35.2	33.1	34.6	36.0	33.4	34.8	35.9	34.0	35.2	36.0	33.5	34.9	36.7
Min....	33.4	34.4	34.9	32.6	34.2	35.6	33.0	34.5	35.5	33.7	34.7	35.6	33.4	34.6	36.4
24 Max....	33.5	34.6	35.3	32.9	34.0	35.9	33.2	34.9	35.9	33.9	35.1	35.9	33.5	34.9	36.7
Min....	33.1	34.1	34.6	32.3	33.5	35.4	32.6	34.3	35.3	33.4	34.5	35.4	33.1	34.4	36.1
25 Max....	33.4	34.6	35.2	32.8	34.4	35.9	33.2	34.7	35.9	33.9	35.0	35.9	33.5	34.9	36.6
Min....	33.4	34.6	35.2	32.8	34.4	35.9	33.2	34.7	35.9	33.9	35.0	35.9	33.5	34.9	36.6
26 Max...	33.3	34.3	35.1	32.4	34.2	35.6	33.0	34.5	35.6	33.6	34.7	35.7	33.4	34.7	36.5
Min....	33.0	34.1	34.7	32.1	33.9	35.4	32.7	34.4	35.4	33.4	34.5	35.4	33.1	34.4	36.2
27 Max....	33.4	34.4	34.9	32.7	34.1	35.5	33.0	34.5	35.5	33.6	34.8	35.7	33.4	34.6	36.4
Min....	32.9	33.9	34.5	32.4	33.8	35.1	32.5	34.0	35.1	33.4	34.4	35.2	32.9	34.2	36.0
28 Max....	33.2	34.0	34.7	32.6	33.9	35.4	32.8	34.3	35.4	33.5	34.5	35.4	33.0	34.4	36.2
Min....	32.9	33.8	34.5	32.4	33.8	35.2	32.6	34.1	35.2	33.4	34.4	35.2	32.9	34.3	35.9
Ave. Max..	33.59	34.69	35.36	32.95	34.52	36.07	33.27	34.91	36.06	33.89	35.07	36.10	33.55	34.90	36.74
Min	33.33	34.41	35.05	32.63	34.25	35.79	32.99	34.61	35.76	33.63	34.78	35.78	33.33	34.63	36.44
Range	0.26	0.28	0.31	0.32	0.27	0.28	0.28	0.30	0.30	0.26	0.29	0.32	0.22	0.27	0.30

TABLE 54.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, MARCH, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2	Max....	33.7	34.5	35.0	33.1	34.3	35.5	33.4	34.6	35.6	34.0	35.0	35.9	33.4	34.8	36.5
	Min....	33.4	34.2	34.7	32.9	34.1	35.3	33.0	34.5	35.5	33.7	34.6	35.6	33.2	34.4	36.2
3	Max....	33.4	34.5	35.0	33.0	34.4	35.6	33.4	34.6	35.6	34.0	35.0	35.9	33.4	34.6	36.3
	Min....	33.2	34.0	34.6	32.6	34.0	35.4	32.9	34.4	35.3	33.5	34.6	35.4	33.1	34.3	36.0
4	Max....	33.4	34.3	34.7	32.8	34.2	35.4	33.1	34.5	35.5	33.8	34.7	35.5	33.4	34.5	36.2
	Min....	33.2	34.1	34.6	32.7	34.0	35.3	33.0	34.4	35.3	33.7	34.6	35.5	33.2	34.3	36.0
5	Max....	33.4	34.4	34.9	33.0	34.4	35.6	33.2	34.5	35.5	33.9	34.8	35.5	33.4	34.6	36.2
	Min....	33.2	34.1	34.6	32.6	34.0	35.2	32.8	34.3	35.2	33.6	34.6	35.4	33.0	34.2	35.9
6	Max....	33.4	34.4	34.8	32.9	33.9	35.0	33.1	34.5	35.5	33.9	34.8	35.5	33.2	34.4	36.2
	Min....	33.3	34.1	34.6	32.7	33.8	34.8	32.9	34.3	35.2	33.6	34.5	35.3	33.1	34.2	35.9
7	Max....	33.5	34.3	34.8	33.0	34.0	35.1	33.2	34.5	35.4	33.7	34.7	35.5	33.2	34.4	36.1
	Min....	33.3	34.2	34.7	32.9	33.9	34.9	33.0	34.4	35.3	33.6	34.6	35.5	33.1	34.3	35.9
9	Max....	33.5	34.4	34.9	33.2	34.4	35.4	33.1	34.5	35.5	33.9	34.8	35.6	33.3	34.5	36.0
	Min....	33.3	34.2	34.7	33.0	34.1	35.3	33.0	34.4	35.2	33.7	34.6	35.4	33.1	34.1	35.8
10	Max....	33.6	34.6	35.0	33.4	34.4	35.5	33.3	34.6	35.6	34.0	34.9	35.6	33.4	34.4	36.3
	Min....	33.4	34.2	34.7	33.0	34.0	35.1	32.9	34.3	35.2	33.6	34.6	35.3	33.0	34.1	35.8
11	Max....	33.5	34.4	35.0	33.4	34.3	35.5	33.4	34.5	35.4	34.0	34.9	35.5	33.3	34.4	36.1
	Min....	33.3	34.1	34.6	33.0	33.9	35.1	32.9	34.3	35.1	33.7	34.5	35.2	33.0	34.1	35.8
12	Max....	33.6	34.5	35.0	33.4	34.4	35.5	33.3	34.5	35.5	34.0	34.9	35.7	33.4	34.4	36.1
	Min....	33.4	34.3	34.7	33.1	34.1	35.2	33.0	34.4	35.2	33.6	34.6	35.3	33.0	34.2	35.8
13	Max....	33.6	34.4	34.9	33.4	34.4	35.5	33.2	34.6	35.5	33.9	34.8	35.5	33.4	34.4	36.0
	Min....	33.3	33.9	34.1	32.7	33.7	34.9	32.8	33.9	34.7	33.4	34.3	34.9	33.0	34.0	35.5
14	Max....	39.2	36.4	35.3	36.5	34.9	35.1	33.0	34.2	35.0	33.6	34.6	35.3	33.1	34.0	35.7
	Min....	33.2	34.1	34.5	32.9	34.0	35.1	32.8	34.0	34.6	33.4	33.5	34.8	32.9	33.6	34.9
16	Max....	43.5	40.6	38.8	45.6	41.2	38.0	40.9	37.0	35.9	42.5	37.5	37.0	33.1	33.9	35.2
	Min....	37.1	38.2	37.5	36.4	37.7	37.2	35.7	35.8	35.5	36.8	36.5	36.6	33.0	33.8	35.0
17	Max....	37.2	37.7	38.1	37.2	37.7	38.4	36.4	37.9	37.1	36.9	37.6	38.1	33.1	34.1	35.6
	Min....	35.3	36.6	36.9	34.9	36.6	37.3	35.4	36.7	36.9	36.5	36.2	37.5	33.0	33.9	35.5
18	Max....	34.9	36.3	37.0	34.4	36.3	37.5	34.9	36.6	37.1	35.5	36.1	37.5	33.3	34.4	36.1
	Min....	34.4	35.7	36.4	34.1	35.9	36.9	34.4	36.2	36.9	35.0	35.6	37.1	33.1	34.4	36.0
19	Max....	34.4	35.4	36.2	33.4	35.4	36.8	34.3	36.0	36.9	34.9	36.1	37.0	33.4	34.6	36.4
	Min....	34.0	35.1	35.9	33.3	34.9	36.4	33.9	35.6	36.5	34.5	35.9	36.7	33.2	34.5	36.2
20	Max....	34.1	35.2	35.8	32.9	34.9	36.4	34.0	35.6	36.6	34.5	35.8	36.5	33.4	34.8	36.6
	Min....	33.9	34.7	35.4	32.4	34.3	35.9	33.6	35.2	36.1	34.1	35.2	36.2	33.1	34.4	36.4
21	Max....	33.9	35.0	35.6	32.4	34.5	36.0	33.8	35.3	36.3	34.1	35.3	36.3	33.4	34.8	36.5
	Min....	33.6	34.6	35.2	31.9	34.1	35.6	33.4	34.9	35.9	33.9	34.2	36.0	33.3	34.5	36.4
23	Max....	33.6	34.5	35.1	32.8	34.3	35.6	33.4	34.9	35.7	33.9	34.4	35.8	33.2	34.5	36.3
	Min....	33.4	34.4	34.9	32.6	34.1	35.4	33.2	34.6	35.5	33.6	33.9	35.5	33.1	34.4	36.1
24	Max....	39.6	36.4	35.5	40.2	36.4	35.6	37.0	34.8	35.7	37.6	34.5	35.7	33.3	34.6	36.4
	Min....	33.4	34.2	34.8	32.6	34.1	35.4	33.1	34.5	35.3	33.5	34.2	35.4	33.1	34.3	35.9
25	Max....	43.9	38.9	37.0	44.2	38.5	36.3	40.4	35.7	35.2	41.2	36.0	35.4	32.5	33.5	35.2
	Min....	35.0	35.4	35.6	34.4	34.9	35.5	34.3	35.0	35.1	34.7	34.4	35.4	32.4	33.4	35.0
26	Max....	47.9	42.1	39.3	48.8	41.7	38.0	44.2	37.9	36.4	45.2	38.4	37.0	32.6	33.6	35.2
	Min....	37.4	37.8	37.7	36.5	37.3	37.1	36.6	37.0	36.2	37.1	37.1	36.8	32.5	33.4	35.0
27	Max....	42.5	43.1	41.9	42.0	42.8	40.5	43.1	41.2	38.7	43.4	41.6	39.8	32.7	33.9	35.4
	Min....	40.4	41.0	40.8	39.9	40.5	40.0	40.7	40.7	37.9	41.1	40.8	39.1	32.6	33.8	35.3
28	Max....	46.7	42.3	40.2	47.3	42.2	39.4	44.5	39.4	38.8	45.0	39.8	39.5	33.0	34.1	35.8
	Min....	37.1	38.5	38.8	36.4	38.3	38.8	37.5	38.9	38.4	38.0	38.7	38.9	32.6	34.0	35.7
30	Max....	43.6	43.7	42.8	43.2	43.2	41.7	44.0	42.6	40.6	44.4	42.9	41.5	39.2	37.3	37.7
	Min....	42.3	42.4	42.1	42.0	42.1	41.6	42.6	42.2	40.3	43.1	42.3	41.1	38.9	36.3	37.1
31	Max....	47.5	43.9	41.9	49.2	44.2	41.2	45.4	41.4	40.5	45.4	41.5	41.1	41.8	38.4	38.7
	Min....	39.1	40.4	40.6	38.5	40.1	40.5	39.7	40.7	40.3	40.0	40.6	40.7	38.8	38.1	38.4
Ave.	Max..	37.35	36.93	36.71	37.10	36.74	36.77	36.35	36.17	36.43	36.97	36.36	36.74	33.77	34.61	36.19
	Min..	34.84	35.71	36.07	34.23	35.48	36.35	34.58	35.75	36.10	35.19	35.74	36.41	33.44	34.35	35.90
	Range	2.51	1.22	0.64	2.87	1.26	0.42	1.77	0.42	0.33	1.78	0.62	0.33	0.33	0.26	0.29

TABLE 55.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, APRIL, 1914.

Date—Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1 Max....	45.7	44.0	42.7	45.9	43.8	42.2	44.9	42.6	41.0	45.3	42.5	41.7	43.3	40.0	39.8
Min....	43.1	42.9	42.4	43.0	42.7	41.8	43.0	42.3	40.8	43.3	42.2	41.4	42.0	39.5	39.5
2 Max....	41.0	41.8	42.2	40.8	41.6	42.1	41.1	42.4	41.2	41.4	42.5	41.9	41.9	40.9	40.5
Min....	39.9	41.1	41.3	39.2	40.9	41.4	40.4	41.5	41.0	40.6	41.3	41.4	11.1	40.8	40.2
3 Max....	42.5	41.3	40.5	43.1	41.4	40.7	41.7	40.6	40.8	42.2	40.5	41.1	40.9	40.8	40.9
Min....	36.4	39.0	39.5	35.7	38.9	40.2	37.7	39.9	40.3	37.8	39.5	40.4	39.1	40.4	40.8
4 Max....	36.9	38.3	39.6	37.4	38.5	40.3	36.6	39.9	40.3	36.9	39.6	40.6	38.6	40.5	41.0
Min....	35.6	37.6	38.7	35.0	37.7	39.5	35.8	38.6	39.7	36.0	38.4	39.6	34.1	40.0	40.8
6 Max....	34.9	37.1	38.1	34.5	37.4	39.0	35.4	38.0	38.7	35.5	37.8	38.6	37.4	38.8	40.1
Min....	34.5	36.3	37.3	34.1	36.4	38.1	34.5	37.1	38.2	34.7	36.9	38.1	36.3	38.4	39.7
7 Max....	37.3	36.6	36.7	37.7	36.8	37.8	35.2	36.7	37.8	36.6	36.4	37.7	35.8	38.1	39.5
Min....	34.2	35.7	36.6	33.7	35.8	37.5	33.9	35.9	37.4	34.4	36.2	37.4	35.3	37.6	39.2
8 Max....	34.3	36.3	37.1	34.4	36.2	37.8	34.1	36.4	37.6	34.7	36.5	37.7	35.3	37.3	39.2
Min....	33.7	35.7	36.4	33.2	35.6	37.3	33.4	35.8	37.1	34.2	36.0	37.1	31.6	36.9	38.5
9 Max....	34.9	35.2	36.3	35.4	35.5	37.1	33.3	35.7	37.1	33.7	35.7	37.2	34.5	36.8	38.5
Min....	33.2	34.8	35.8	32.9	35.1	36.8	33.1	35.3	36.7	33.4	35.3	36.7	31.3	36.3	38.2
10 Max....	39.0	36.9	36.5	41.3	37.8	36.8	35.6	35.3	36.6	36.3	35.2	36.6	34.1	36.2	38.2
Min....	33.3	34.7	35.5	33.2	34.7	36.5	33.0	34.9	36.2	33.2	34.7	36.1	33.9	35.8	37.7
11 Max....	42.3	39.4	38.3	44.3	40.4	38.2	39.2	36.8	36.6	40.1	37.2	36.8	35.4	35.8	37.5
Min....	36.9	37.4	37.5	37.3	37.7	37.7	35.8	36.3	36.5	36.6	36.6	36.6	33.8	35.4	37.1
13 Max....	50.1	43.5	40.5	52.3	44.2	40.0	46.4	39.1	38.1	45.7	39.5	38.8	38.6	36.7	37.5
Min....	35.8	38.4	38.4	35.8	38.6	39.0	36.9	38.1	37.9	37.2	38.2	38.4	36.9	36.6	37.4
14 Max....	55.5	47.4	43.5	56.9	47.7	41.9	52.2	42.0	39.3	51.0	42.4	40.0	43.0	37.6	38.0
Min....	38.9	41.1	40.6	38.2	41.1	40.4	39.6	40.1	39.2	39.7	40.2	39.6	38.9	37.4	37.8
15 Max....	54.2	49.0	45.9	54.6	48.6	44.1	52.2	45.1	41.5	51.2	45.2	42.4	45.4	39.8	39.0
Min....	45.4	45.5	44.2	45.0	45.1	43.1	45.7	44.0	41.0	45.3	43.8	41.9	43.0	39.0	38.6
16 Max....	55.6	49.8	46.8	56.2	49.6	45.0	53.8	46.2	43.0	52.6	46.4	43.8	47.0	41.5	40.4
Min....	45.3	46.2	45.1	44.5	45.6	44.1	46.0	45.1	42.7	45.7	45.0	43.6	44.8	41.0	39.9
17 Max....	61.3	53.1	48.9	62.2	53.0	46.5	57.9	48.0	44.0	56.5	47.5	44.9	50.2	43.1	41.6
Min....	46.0	47.4	46.2	44.9	46.8	4.51	47.3	46.4	43.9	46.8	45.8	44.7	46.5	42.7	41.3
18 Max....	65.0	56.5	51.9	65.4	55.9	49.0	61.6	51.2	45.9	60.4	50.9	47.0	53.9	45.2	43.1
Min....	53.0	51.5	49.7	52.8	51.0	47.9	52.8	49.6	45.3	52.2	49.5	46.5	50.4	44.4	42.5
20 Max....	45.9	48.6	49.5	45.5	47.7	48.7	47.4	50.7	48.4	47.3	50.1	49.3	49.6	48.4	46.5
Min....	44.1	46.6	47.1	42.9	45.6	46.6	45.8	48.1	47.5	45.8	47.5	47.9	48.0	48.0	46.0
21 Max....	53.7	48.4	46.4	55.3	48.9	45.7	51.4	46.6	46.6	50.7	46.0	46.7	48.4	47.5	46.8
Min....	41.5	44.3	44.8	40.4	43.9	45.0	43.3	45.6	45.5	43.1	44.9	45.6	45.9	46.6	46.4
22 Max....	58.4	52.3	49.2	59.5	52.4	47.9	55.6	48.6	45.9	54.9	48.6	46.5	51.4	46.9	46.3
Min....	48.8	48.6	47.8	48.3	48.4	47.1	49.2	47.9	45.8	48.8	47.5	46.3	49.0	46.8	46.3
23 Max....	57.5	52.8	49.9	58.1	52.6	48.7	55.4	49.8	47.0	54.3	49.2	47.7	51.5	47.5	46.5
Min....	46.4	48.8	48.2	45.5	48.2	47.7	48.3	48.6	46.9	47.4	48.0	47.3	48.9	47.4	46.3
24 Max....	54.6	51.2	49.8	54.8	50.9	48.9	53.1	50.0	47.5	52.5	49.4	48.0	50.9	47.8	46.8
Min....	49.0	49.5	49.0	48.4	49.0	48.2	49.9	49.3	47.2	48.9	48.6	47.7	49.6	47.6	46.7
25 Max....	58.9	54.4	51.7	60.6	55.0	50.3	57.6	51.1	47.9	57.6	51.3	48.4	54.3	48.3	47.2
Min....	51.9	50.6	49.9	51.8	50.3	48.7	51.4	50.0	47.6	51.1	49.7	48.1	51.0	47.9	46.9
27 Max....	65.4	58.7	54.5	67.1	59.9	52.8	62.8	53.6	49.4	62.5	53.9	50.5	57.5	50.6	48.9
Min....	51.3	52.6	51.7	51.0	52.8	51.0	52.3	51.9	49.3	52.0	51.4	50.2	53.8	50.5	48.5
28 Max....	65.9	60.6	56.8	69.4	62.0	54.9	64.2	56.4	51.4	63.9	56.7	52.6	61.2	52.8	50.2
Min....	56.9	56.5	54.9	56.8	56.4	53.7	57.3	55.2	51.1	56.9	54.8	52.1	57.7	52.1	49.5
29 Max....	59.0	58.4	56.9	59.0	58.6	55.6	59.9	57.3	52.8	59.9	57.3	53.9	60.6	54.7	51.9
Min....	58.0	57.2	56.1	58.4	57.2	54.8	58.7	56.7	52.5	58.5	56.5	53.8	59.6	54.1	51.0
30 Max....	56.9	54.7	53.2	59.2	55.8	53.1	56.5	54.5	52.9	55.1	53.9	53.6	55.8	55.0	52.6
Min....	47.5	51.0	51.8	46.3	50.8	51.8	50.7	53.2	51.7	50.1	52.3	52.1	53.9	54.0	52.6
Ave. Max..	50.26	47.17	45.52	51.19	47.39	44.81	48.66	45.18	43.43	48.42	45.08	44.00	46.02	43.41	43.02
Min..	43.10	44.27	44.10	42.63	44.09	43.88	43.68	44.13	43.04	43.49	43.88	43.48	43.94	42.97	42.67
Range	7.16	2.90	1.42	8.56	3.30	0.93	4.98	1.05	0.39	4.93	1.20	0.52	2.08	0.44	0.35

TABLE 56.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, MAY, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	54.8	52.2	51.6	55.8	52.5	52.1	54.2	52.6	51.6	54.0	51.5	51.9	53.6	53.8	52.7
	Min....	46.7	49.6	50.1	45.3	49.4	50.5	48.6	51.2	50.5	47.8	49.9	50.6	50.8	52.5	52.1
2	Max....	60.7	54.0	51.4	62.8	54.4	50.6	58.3	51.3	50.4	58.4	50.5	50.7	55.3	52.2	51.9
	Min....	46.5	49.5	49.5	45.0	49.0	49.6	48.0	50.1	49.6	47.9	49.2	49.9	50.5	51.4	51.3
4	Max ...	62.0	57.3	54.7	62.8	57.6	53.4	60.5	54.6	51.3	60.9	54.4	52.5	58.5	53.2	51.4
	Min....	54.2	54.4	53.4	53.8	54.2	52.5	55.0	53.9	51.1	55.1	53.0	52.2	56.5	53.0	51.3
5	Max...	60.8	56.9	55.4	61.4	56.8	54.2	59.6	55.9	52.4	60.0	55.2	53.6	58.5	54.2	52.3
	Min....	57.4	56.1	55.1	56.9	55.7	53.9	57.5	55.5	52.1	57.8	54.8	53.5	57.9	53.9	51.9
6	Max ...	59.6	57.1	55.1	61.4	57.5	54.1	59.6	55.6	52.9	60.0	54.7	54.1	58.6	54.8	52.9
	Min....	53.4	54.8	54.1	52.1	54.2	53.3	54.8	54.8	52.6	54.8	53.9	53.5	56.5	54.5	52.8
7	Max....	55.8	54.3	53.9	56.8	54.5	53.6	55.2	54.8	52.9	55.9	53.8	53.9	55.9	54.9	53.4
	Min....	50.0	53.0	52.9	48.8	52.7	52.6	51.8	53.6	52.3	52.1	52.8	53.2	54.4	54.4	53.2
8	Max....	54.6	53.4	52.7	54.9	53.4	52.4	54.4	53.3	52.1	54.9	52.5	53.0	54.9	54.2	53.3
	Min....	50.6	51.9	52.0	49.6	51.5	52.0	51.7	52.8	51.5	52.1	51.9	52.4	53.5	53.7	53.1
9	Max....	62.6	56.1	53.0	65.0	56.9	52.1	60.1	52.5	51.1	61.1	52.9	52.2	57.1	53.6	53.0
	Min....	47.2	50.3	50.8	45.7	49.8	50.6	48.6	51.3	50.9	48.8	51.1	51.5	52.3	52.9	52.6
11	Max...	55.6	57.7	57.3	54.4	57.6	56.3	57.5	57.5	53.9	57.6	57.9	55.2	59.5	55.4	53.4
	Min....	50.6	53.4	54.3	49.4	52.8	54.0	52.0	55.1	53.4	51.8	54.8	54.9	55.3	55.2	52.9
12	Max....	47.3	49.0	50.9	46.5	48.4	51.3	47.3	51.4	52.6	47.3	50.5	52.7	49.1	54.0	54.3
	Min....	46.0	48.4	49.5	45.0	48.0	49.9	46.8	49.9	51.1	46.4	49.1	50.9	48.0	52.1	53.8
13	Max....	53.4	50.3	49.3	54.6	50.5	49.2	51.8	49.0	50.0	52.2	48.7	49.8	49.4	51.0	52.8
	Min....	44.9	47.3	48.2	44.1	47.0	48.8	45.6	48.4	49.1	45.5	47.9	49.0	47.1	50.0	51.6
14	Max....	54.8	52.4	50.5	57.0	53.4	50.0	53.9	48.6	49.3	54.6	50.0	49.7	51.9	50.2	51.3
	Min....	44.0	47.5	48.4	42.4	47.3	48.8	45.2	48.4	48.7	45.2	48.0	49.1	47.8	49.6	50.6
15	Max....	58.6	53.4	50.9	62.1	54.2	50.4	56.5	50.1	49.4	57.8	50.8	50.0	53.2	50.1	50.5
	Min....	45.1	48.8	49.1	43.9	48.7	49.4	46.6	49.0	48.9	46.8	48.9	49.6	48.9	49.7	50.2
16	Max....	61.8	54.7	52.0	64.4	55.3	51.4	58.6	51.4	49.8	59.8	52.0	50.8	54.3	50.6	50.3
	Min....	47.5	50.6	50.5	46.7	50.6	50.5	48.9	50.3	49.5	49.4	50.9	50.5	51.3	50.3	50.1
18	Max....	68.1	60.3	56.4	69.8	60.7	54.4	65.7	55.6	51.9	66.0	56.6	53.4	60.7	52.7	51.4
	Min....	53.2	55.0	53.9	52.3	54.5	53.3	54.4	54.1	51.8	54.6	54.4	53.1	55.2	52.6	51.1
19	Max....	71.1	62.8	58.4	73.3	62.9	56.2	68.8	58.1	53.5	68.9	58.7	55.0	64.1	54.6	52.5
	Min....	56.0	57.5	56.4	55.0	57.1	55.1	57.3	56.6	53.3	57.3	56.6	54.8	58.2	54.3	52.1
20	Max....	72.2	64.4	60.4	73.4	64.4	58.1	70.3	60.3	55.1	70.1	60.5	56.9	66.4	56.8	53.9
	Min....	59.2	60.0	58.4	58.3	59.6	56.9	60.3	59.0	55.1	60.3	59.1	56.8	61.6	56.4	53.4
21	Max....	72.9	65.3	61.7	73.6	64.6	59.3	71.1	61.9	56.9	70.8	62.2	58.5	68.0	58.8	55.7
	Min....	61.1	61.6	60.1	59.9	61.1	58.4	62.0	60.9	56.7	61.9	60.6	58.3	63.6	58.7	55.1
22	Max ...	70.8	65.6	62.5	71.6	65.5	60.6	69.4	63.1	58.3	70.0	63.2	59.8	68.2	60.9	57.5
	Min....	64.3	63.1	61.8	63.8	62.5	60.0	65.1	62.5	57.9	65.0	62.5	59.8	65.7	60.5	56.7
23	Max....	70.1	64.1	61.3	71.5	64.2	60.0	68.8	62.4	58.9	68.9	62.1	60.5	66.8	61.9	58.8
	Min....	57.4	60.4	59.9	55.4	59.7	58.7	59.6	61.1	58.2	59.7	60.7	59.6	63.0	61.4	58.3
25	Max...	73.7	65.3	61.4	76.1	66.1	59.6	71.4	61.2	57.7	71.3	61.7	58.5	67.9	60.7	59.0
	Min....	58.8	58.5	58.4	58.1	58.2	57.7	59.3	59.2	57.2	59.3	59.2	58.2	61.4	60.4	58.9
26	Max....	77.9	69.3	64.9	79.9	69.0	62.8	75.8	64.8	59.1	75.8	65.4	61.2	72.6	62.4	59.4
	Min....	66.0	64.9	63.1	65.8	64.1	61.5	66.7	63.4	58.4	66.7	63.8	60.4	67.7	61.8	59.1
27	Max...	73.6	68.8	66.1	73.9	68.9	64.6	72.8	67.7	61.9	72.8	67.3	63.4	71.5	64.8	60.9
	Min....	69.0	67.0	65.7	68.4	66.9	64.2	69.7	66.7	61.9	69.9	66.7	63.3	70.1	64.1	60.0
28	Max....	70.9	67.3	65.5	74.5	68.1	64.1	70.6	66.6	62.4	70.9	66.4	63.8	70.2	65.5	62.4
	Min....	66.1	65.6	64.6	65.3	65.1	63.4	67.5	65.9	62.1	67.3	65.8	63.4	68.7	65.4	61.9
29	Max....	76.9	70.2	66.2	76.8	70.3	64.2	76.6	66.4	62.2	76.8	67.1	63.6	73.4	65.6	62.8
	Min....	63.3	64.1	63.9	63.5	64.7	62.9	64.8	64.8	61.9	64.9	64.8	63.1	67.7	65.3	62.7
30	Max....	74.2	69.2	66.5	76.4	69.3	64.7	73.8	67.1	63.0	74.2	67.0	64.7	72.8	66.7	63.6
	Min....	65.0	66.2	65.1	63.5	65.3	63.8	66.9	66.5	62.9	66.7	66.1	64.2	69.4	66.5	63.3
Ave.	Max..	64.42	59.67	57.31	65.80	59.88	56.14	63.18	57.49	54.64	63.50	57.45	55.75	61.25	56.68	55.05
	Min..	54.75	56.13	55.74	53.77	55.76	55.09	55.95	56.35	54.18	55.97	56.02	55.23	57.81	56.18	54.62
	Range	9.67	3.54	1.57	12.03	4.12	1.05	7.23	1.14	0.46	7.53	1.43	0.52	3.44	0.50	0.43

TABLE 57.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, JUNE, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	Max....	78.0	71.0	67.2	79.2	70.7	65.4	76.9	67.5	63.4	76.5	67.9	65.0	74.1	66.9	64.2
	Min....	65.5	66.6	65.4	64.6	66.0	64.3	67.1	66.4	63.1	67.3	66.2	64.7	69.1	66.6	64.1
2	Max....	77.1	70.0	66.6	78.3	70.1	65.4	75.3	67.7	64.1	74.7	67.4	65.6	73.0	67.4	64.6
	Min....	62.4	65.6	64.9	59.9	64.7	63.8	64.6	66.0	63.4	64.3	65.6	64.6	67.8	66.7	64.4
3	Max....	71.3	68.3	66.5	71.4	68.2	65.4	71.2	67.5	63.9	70.8	66.9	65.4	71.1	67.3	64.7
	Min....	64.1	66.1	65.3	62.7	65.4	64.3	65.9	66.4	63.6	65.4	65.7	64.7	68.4	66.9	64.6
4	Max....	66.7	65.9	65.6	66.4	65.4	64.6	66.9	66.7	63.9	66.8	66.3	64.9	68.7	66.8	64.9
	Min....	65.0	65.4	65.0	64.2	65.1	64.1	66.4	66.1	63.6	66.3	65.7	64.6	68.1	66.6	64.7
5	Max....	66.1	63.8	62.6	68.0	64.2	62.5	66.0	64.1	63.0	66.4	63.5	63.8	66.4	66.2	64.8
	Min....	58.3	61.4	61.8	56.7	60.8	61.5	60.5	63.0	62.0	60.0	62.3	62.7	64.0	65.1	64.6
6	Max....	72.8	65.5	62.7	75.0	66.6	62.1	70.2	62.6	61.7	70.7	63.1	62.4	67.4	64.8	64.1
	Min....	56.9	59.9	60.6	55.7	59.9	60.8	58.6	61.5	60.8	58.8	61.4	61.6	62.9	63.9	63.5
8	Max....	85.7	75.9	70.8	86.2	76.6	68.0	83.4	70.0	63.8	82.9	70.9	65.7	80.1	66.9	63.8
	Min....	70.6	69.5	68.2	70.6	69.6	66.3	71.1	68.0	63.1	71.1	68.1	65.1	72.4	66.2	63.2
9	Max....	86.7	78.0	73.4	87.1	77.3	70.2	84.9	73.0	66.3	84.1	73.3	68.4	82.8	70.0	65.6
	Min....	74.1	73.2	71.2	73.5	72.8	68.9	74.7	71.5	65.6	74.4	71.2	67.9	76.9	69.4	64.7
10	Max....	87.4	79.2	74.9	87.0	78.1	71.4	85.9	74.9	68.1	85.1	74.4	70.2	84.8	72.5	67.8
	Min....	75.1	74.9	73.1	74.1	73.4	70.3	76.5	73.6	67.9	76.0	72.7	70.0	78.9	72.1	66.7
11	Max....	81.9	76.0	74.1	81.5	74.0	71.6	80.8	75.1	69.4	80.3	73.9	71.3	80.5	74.1	69.3
	Min....	73.8	73.7	72.9	72.2	71.5	70.5	75.1	73.9	69.2	74.5	72.4	70.6	77.7	73.8	68.8
12	Max....	81.5	75.3	72.5	80.6	74.3	70.5	80.6	73.6	69.2	80.0	72.1	70.8	80.6	74.1	70.0
	Min....	70.1	71.4	71.2	68.9	70.3	69.4	71.9	72.3	68.6	71.4	70.6	69.9	75.8	73.4	69.9
13	Max....	78.9	74.6	72.0	78.1	72.8	70.0	78.8	73.0	69.5	78.0	71.4	70.3	79.6	73.9	70.1
	Min....	70.5	71.7	70.9	68.9	69.8	69.1	71.8	71.8	68.7	71.3	70.2	69.6	75.9	73.4	70.1
15	Max....	78.2	73.6	71.1	77.4	72.7	69.4	77.9	71.8	68.4	77.4	70.6	69.6	78.4	73.1	70.0
	Min....	68.7	70.4	69.8	67.2	69.7	68.5	70.1	70.7	67.9	69.8	69.3	68.9	74.4	72.4	69.9
16	Max....	77.4	71.2	69.1	76.1	70.1	68.5	76.1	70.5	68.1	75.5	68.9	69.3	75.9	72.5	69.9
	Min....	63.4	67.0	67.6	62.0	66.2	66.9	65.4	68.7	66.9	65.0	66.9	67.8	70.6	71.1	69.4
17	Max....	79.8	72.3	69.2	78.3	71.2	67.7	77.8	69.5	67.0	77.1	68.2	68.1	76.6	71.3	69.2
	Min....	64.3	67.4	67.5	62.6	66.3	66.5	65.9	68.0	66.3	65.4	66.3	67.1	70.4	70.4	68.8
18	Max....	80.9	73.5	70.2	79.1	72.2	68.3	78.9	70.1	66.9	78.3	69.3	68.1	77.6	71.1	68.6
	Min....	66.6	68.9	68.5	65.0	67.8	67.1	67.9	68.8	66.5	67.1	67.2	67.5	71.7	70.5	68.5
19	Max....	70.1	71.1	70.6	69.0	70.3	69.1	71.1	71.1	67.4	70.4	69.9	68.7	74.4	71.4	68.7
	Min....	66.7	67.9	68.0	66.0	67.1	67.3	68.4	68.9	67.0	67.9	67.8	68.0	71.2	70.8	68.6
20	Max....	72.7	67.5	65.5	73.2	67.3	64.9	71.3	66.4	66.3	71.2	65.0	66.8	70.6	69.8	68.6
	Min....	57.7	62.6	63.8	55.3	61.6	63.8	59.8	65.0	64.8	59.6	63.5	65.2	65.2	68.3	67.9
22	Max....	75.0	68.4	66.1	75.4	68.0	65.2	72.6	66.1	64.3	73.1	65.6	65.1	69.8	67.1	66.6
	Min....	64.7	64.9	64.8	64.0	64.6	64.6	65.3	65.4	63.9	65.2	64.6	64.7	66.9	66.7	66.3
23	Max....	78.9	72.8	69.5	82.6	72.3	68.0	77.3	69.1	64.9	77.9	69.7	66.4	74.8	67.7	66.2
	Min....	69.7	68.5	67.5	68.8	67.4	66.8	69.9	67.9	64.6	69.8	67.1	65.9	70.5	66.4	66.1
24	Max....	82.9	75.4	71.6	84.9	76.3	70.1	80.7	71.3	66.5	80.9	72.1	68.2	77.8	69.7	67.0
	Min....	71.1	70.9	69.8	71.1	71.1	68.9	71.9	70.0	66.2	72.1	70.4	67.9	73.1	69.2	66.7
25	Max....	83.6	77.4	73.4	85.8	78.0	71.2	83.4	73.2	67.9	83.1	73.5	69.7	80.5	71.2	68.3
	Min....	72.0	72.4	71.2	71.6	72.4	70.0	73.3	71.8	67.8	73.3	71.6	69.6	74.6	71.0	67.8
26	Max....	73.8	74.0	73.5	75.9	73.5	72.0	75.4	74.1	69.3	75.2	74.1	71.1	76.5	72.8	69.6
	Min....	69.3	73.2	72.2	66.2	72.7	70.7	74.2	73.0	69.2	73.9	72.9	70.6	75.5	72.7	69.0
27	Max....	69.1	70.0	69.9	67.9	69.9	69.3	72.9	71.3	69.3	73.1	70.7	70.4	71.8	72.6	70.2
	Min....	64.2	68.2	68.8	67.2	68.3	68.0	68.5	70.0	68.2	68.1	69.6	69.8	69.9	71.5	70.0
29	Max....	65.8	64.6	64.7	69.4	65.1	65.1	66.7	66.2	66.2	67.1	65.4	66.6	66.9	69.4	69.2
	Min....	58.4	62.4	63.8	53.4	62.1	64.2	61.9	64.8	64.8	61.6	64.3	65.1	64.6	67.9	68.4
30	Max....	75.4	68.9	65.7	73.1	70.0	65.1	73.8	65.4	64.4	73.8	65.6	65.0	71.3	67.5	67.5
	Min....	57.7	62.3	63.2	58.1	62.3	63.6	61.1	63.9	63.7	61.2	63.5	64.3	65.3	66.7	66.8
Ave.	Max.	76.83	71.01	69.19	77.19	71.36	67.73	76.03	69.68	66.28	75.78	69.22	67.57	75.08	69.93	67.44
	Min..	66.19	67.94	67.58	65.02	67.27	66.55	67.99	68.36	65.67	67.72	67.58	66.87	70.84	69.22	67.06
	Range	10.64	3.07	1.61	12.17	4.09	1.18	8.04	1.32	0.61	8.06	1.64	0.80	4.24	0.71	0.38

TABLE 58.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, JULY, 1914

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	66.8	66.7	66.7	66.9	66.8	66.5	66.9	67.0	64.6	66.9	67.0	65.7	69.2	67.5	66.5
	Min....	64.5	65.4	65.4	63.1	65.3	65.1	65.2	65.9	64.4	65.1	65.7	65.3	67.6	67.1	66.3
2	Max....	69.5	66.3	65.0	71.4	66.9	64.5	69.3	65.1	64.3	69.9	65.1	65.1	68.9	66.7	66.2
	Min....	61.4	63.3	63.9	60.2	62.9	63.8	62.6	64.6	63.6	62.5	64.0	64.4	65.4	66.1	65.9
3	Max....	77.8	70.4	66.8	79.9	71.4	65.9	75.8	66.4	63.9	76.2	67.0	65.0	73.6	66.5	65.8
	Min....	60.9	63.6	64.1	60.0	63.5	63.9	62.9	64.7	63.6	63.1	64.5	64.6	66.5	66.1	65.5
4	Max....	72.3	71.0	68.3	72.7	71.4	67.1	75.7	68.2	65.0	75.6	68.6	66.3	73.8	67.6	65.9
	Min....	66.6	67.9	67.8	60.2	67.6	66.4	67.9	67.4	64.7	67.9	67.4	66.2	70.2	67.5	65.7
6	Max....	85.0	76.9	72.6	85.9	77.1	70.5	82.8	72.3	67.3	82.1	71.9	69.0	81.1	70.7	67.8
	Min....	70.0	71.5	70.3	68.8	71.1	69.2	71.3	70.8	67.1	70.8	69.8	68.8	74.5	70.6	67.1
7	Max....	84.6	77.5	73.6	84.7	77.4	71.4	82.9	73.6	68.7	82.3	73.2	70.4	81.9	72.5	69.2
	Min....	71.4	73.1	71.6	69.8	72.4	70.3	72.6	72.2	68.6	71.8	70.9	70.0	76.2	72.4	68.5
8	Max....	84.9	77.6	74.1	84.4	77.3	72.0	83.1	74.4	69.8	82.5	73.8	71.2	82.2	73.9	70.3
	Min....	73.5	73.5	72.6	72.4	73.1	71.1	74.4	73.4	69.6	73.8	72.3	70.9	77.0	73.7	69.8
9	Max....	86.0	78.2	74.6	85.4	77.9	72.4	84.1	74.6	70.3	83.3	73.9	71.9	83.1	74.8	71.3
	Min....	72.4	73.9	72.7	70.6	73.3	71.3	73.7	73.6	70.1	72.7	72.1	71.3	77.4	74.5	70.9
10	Max....	88.6	80.2	76.1	87.7	79.8	73.5	86.6	76.2	71.0	85.7	75.3	72.6	85.4	75.7	72.0
	Min....	73.9	75.0	74.8	72.3	74.5	72.2	74.9	74.6	70.9	74.1	73.3	72.2	78.3	75.4	71.7
11	Max....	87.4	80.8	77.4	86.3	80.1	74.7	86.1	77.7	72.1	85.5	76.9	73.8	85.9	77.0	73.1
	Min....	77.5	77.4	75.8	76.1	76.6	74.0	78.2	76.6	71.9	77.4	75.1	73.4	81.2	76.9	72.7
13	Max....	80.4	77.0	76.8	79.6	76.7	75.3	79.6	77.9	73.7	79.5	76.8	74.8	81.1	78.2	74.7
	Min....	76.0	76.9	75.8	73.9	76.0	74.3	77.7	77.0	73.4	77.0	75.9	74.5	80.6	77.9	74.5
14	Max....	73.6	73.8	74.1	72.6	73.3	73.4	74.6	75.6	72.9	74.4	74.4	73.9	77.6	77.4	74.9
	Min....	72.4	73.0	72.6	71.0	72.5	71.9	74.4	74.1	71.9	73.9	73.6	72.8	76.5	76.5	74.6
15	Max....	77.9	73.6	71.8	78.4	73.6	71.2	77.1	73.0	71.2	77.0	72.4	72.0	76.9	75.5	74.1
	Min....	69.8	70.7	70.9	68.7	70.4	70.4	71.4	72.1	70.3	71.2	71.7	71.1	74.1	74.6	73.6
16	Max....	85.2	77.6	73.9	88.6	79.1	72.8	84.0	74.1	70.4	83.4	73.8	71.4	81.5	74.6	73.1
	Min....	71.0	72.0	71.7	70.1	71.6	70.9	72.5	72.6	70.1	72.2	71.8	71.1	75.2	74.1	72.6
17	Max....	86.3	79.9	76.6	87.3	80.5	74.9	85.4	76.6	71.5	84.3	76.5	73.1	84.1	76.8	73.0
	Min....	74.6	75.6	74.4	75.1	76.1	73.7	76.9	75.4	71.3	76.1	74.6	72.9	78.9	75.6	72.8
18	Max....	76.6	75.2	75.5	76.1	74.8	74.8	76.5	76.6	72.6	75.6	75.5	74.0	78.6	76.9	73.7
	Min....	72.5	73.8	73.5	71.3	73.6	72.8	74.5	74.6	72.0	73.4	73.5	73.0	77.3	76.1	73.6
20	Max....	83.6	75.9	72.4	83.6	76.1	71.2	81.8	72.6	70.0	80.5	72.1	70.7	79.6	73.8	72.6
	Min....	67.7	70.0	70.0	66.1	69.8	69.7	69.2	70.9	69.5	68.5	69.9	70.1	73.0	73.1	71.9
21	Max....	83.9	77.8	74.3	84.1	77.5	72.6	83.2	74.1	70.4	82.1	72.7	71.4	81.7	74.1	71.9
	Min....	71.2	72.9	72.3	69.9	72.6	71.5	72.3	72.8	70.1	71.3	72.0	71.1	75.9	73.9	71.8
22	Max....	85.6	79.6	76.1	85.6	79.2	74.0	85.4	76.1	71.4	84.1	73.9	72.7	84.1	75.4	72.6
	Min....	73.8	75.4	74.1	73.1	74.9	72.9	75.5	74.5	71.2	74.5	73.5	72.2	78.5	75.2	72.3
23	Max....	79.4	77.6	76.9	78.3	77.1	75.2	80.3	77.4	72.7	79.8	75.1	74.0	81.1	76.9	73.7
	Min....	76.9	76.9	75.9	76.6	76.4	74.4	78.4	76.6	72.5	77.8	74.4	73.8	80.3	76.7	73.1
24	Max....	80.1	77.4	75.4	77.8	77.1	74.0	77.3	76.0	72.7	76.7	74.7	74.0	80.6	75.9	74.1
	Min....	73.9	74.3	74.2	72.1	74.5	73.3	75.9	73.9	72.4	75.4	72.3	73.5	77.9	76.2	73.9
25	Max....	86.4	80.3	76.8	84.9	79.9	74.6	85.9	76.9	72.5	84.6	76.5	73.4	84.6	76.5	74.0
	Min....	72.3	74.5	74.0	70.9	74.0	72.9	74.6	74.8	72.1	74.0	73.4	73.4	77.4	76.3	74.0
27	Max....	78.8	77.6	77.3	77.8	77.0	75.8	78.8	78.0	73.9	78.1	76.4	75.3	80.6	78.2	75.0
	Min....	75.5	77.0	76.3	74.0	76.2	74.8	77.6	76.9	73.7	76.6	74.9	74.6	80.2	77.8	74.8
28	Max....	78.3	74.9	73.7	77.8	74.7	73.0	78.7	75.0	73.2	78.3	72.8	74.1	78.6	77.3	75.2
	Min....	68.9	72.1	72.6	66.6	71.3	71.9	72.0	73.9	72.2	71.4	71.8	72.9	75.5	76.1	74.8
29	Max....	79.6	74.3	71.9	78.9	74.4	71.8	79.1	73.4	71.8	78.2	71.4	72.5	78.1	76.0	74.5
	Min....	69.4	69.6	70.4	68.5	68.9	70.1	70.0	71.7	70.8	69.8	70.3	71.4	72.8	74.6	73.9
30	Max....	81.0	75.1	72.4	80.6	75.1	71.6	80.0	73.0	71.1	78.9	71.1	71.8	78.3	74.9	73.6
	Min....	66.0	70.3	70.6	63.4	69.8	70.3	68.8	71.5	70.1	67.8	69.6	70.9	72.8	73.9	73.0
31	Max....	80.4	75.8	73.3	78.4	75.4	72.2	79.9	73.4	70.8	78.9	72.3	71.7	78.8	74.6	73.0
	Min....	69.7	71.7	71.8	67.2	71.3	71.3	71.4	72.3	70.4	70.5	70.9	71.1	74.2	73.9	72.7
Ave.	**Max..**	80.74	75.89	73.50	80.58	75.84	72.11	80.03	73.90	70.36	79.42	73.00	71.56	79.67	74.33	71.92
	Min..	70.88	72.28	71.86	69.33	71.86	70.90	72.47	72.58	69.94	71.90	71.45	71.02	75.39	73.81	71.56
	Range	9.86	3.61	1.64	11.25	3.98	1.21	7.56	1.32	0.42	7.52	1.55	0.54	4.28	0.52	0.36

TABLE 59. MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, AUGUST, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	82.1	77.1	74.5	80.4	76.5	72.6	81.5	74.2	70.9	80.7	72.6	71.9	80.4	74.6	72.6
	Min....	70.8	73.4	72.9	69.8	72.9	71.8	72.6	73.1	70.8	71.7	70.4	71.6	75.6	74.1	72.5
3	Max....	82.1	77.4	74.6	81.0	76.6	73.2	82.0	74.8	71.8	81.0	73.4	72.9	80.6	75.4	73.3
	Min....	71.1	73.6	73.2	69.3	72.8	72.1	73.3	73.8	71.5	72.3	72.2	72.4	76.3	74.9	73.2
4	Max....	83.3	76.9	74.1	81.8	75.8	73.0	81.6	74.6	72.0	80.6	73.0	73.1	79.2	75.7	73.5
	Min....	68.7	72.3	72.5	67.4	71.4	71.7	70.8	73.1	71.4	69.8	70.7	72.1	74.6	74.9	73.4
5	Max....	83.8	77.0	74.1	82.2	75.8	73.1	81.8	74.6	71.9	80.6	72.5	72.9	79.8	75.5	73.6
	Min....	70.4	72.7	72.8	68.9	71.8	71.9	71.7	73.2	71.2	70.6	70.8	72.0	74.5	74.9	73.3
6	Max....	76.7	77.0	74.7	81.0	75.9	73.5	81.2	74.9	71.9	80.4	72.9	72.9	79.5	75.6	73.5
	Min....	72.5	73.7	73.7	71.6	72.9	72.6	73.6	74.0	71.5	72.6	72.2	72.5	75.1	75.0	73.5
7	Max....	86.0	79.3	76.1	84.6	78.0	73.8	84.8	75.9	72.1	83.6	74.1	73.4	82.6	75.6	73.6
	Min....	73.5	74.8	74.1	71.8	73.9	72.9	74.6	74.6	71.9	73.6	72.8	73.0	77.3	75.4	73.6
8	Max....	87.9	80.0	76.9	85.8	78.6	74.9	85.8	76.8	72.9	84.6	74.9	74.3	83.1	76.6	74.1
	Min....	74.0	75.7	75.0	73.0	74.6	74.0	75.3	75.5	72.9	74.1	72.9	73.9	78.0	76.3	73.9
10	Max....	80.1	76.9	76.8	78.3	76.1	75.4	79.1	77.3	74.1	78.7	75.8	75.3	79.1	77.6	75.3
	Min....	75.3	76.4	75.8	74.4	75.5	74.6	76.4	76.5	73.9	75.7	75.0	74.8	78.0	77.3	75.0
11	Max....	78.6	73.7	73.7	76.9	73.8	73.1	76.2	74.9	73.5	75.9	73.8	74.3	77.0	76.9	75.4
	Min....	73.1	71.5	72.4	72.6	70.7	71.8	71.5	73.9	72.3	70.8	72.0	72.9	74.6	75.3	74.9
12	Max....	79.1	73.5	71.4	80.1	73.8	71.3	78.2	72.7	71.9	77.3	71.2	72.6	76.1	75.4	74.6
	Min....	65.5	69.0	69.8	62.9	68.6	70.1	68.4	71.3	70.8	67.7	70.1	71.2	71.7	74.1	74.0
13	Max....	72.9	71.7	71.5	73.0	71.4	71.4	72.8	72.8	70.9	72.3	71.7	71.7	73.9	74.1	73.5
	Min....	68.6	70.7	70.9	67.3	70.4	70.8	70.6	71.9	70.5	69.9	71.1	71.1	72.9	73.6	73.1
14	Max....	70.9	70.2	69.8	70.6	70.4	69.5	71.6	70.5	70.0	71.7	69.9	70.7	71.9	72.8	72.6
	Min....	65.1	67.9	68.7	0˙89	67.4	68.8	66.8	69.6	69.2	66.5	68.9	69.7	69.9	71.9	72.1
15	Max....	76.7	71.0	69.0	78.6	72.1	68.8	75.8	69.3	68.9	67.6	69.2	69.5	72.2	71.4	71.7
	Min....	62.5	66.1	67.0	59.8	66.1	67.6	64.6	68.0	68.1	64.4	67.4	68.5	67.6	70.4	71.0
17	Max....	75.6	72.0	70.5	76.4	72.6	69.9	74.9	70.4	68.4	75.4	70.6	69.4	73.8	70.4	70.0
	Min....	67.4	69.3	69.3	66.6	69.1	69.1	68.9	69.7	68.2	68.6	69.3	69.2	70.2	70.1	69.8
18	Max....	80.6	74.8	72.2	82.1	75.4	71.1	79.0	71.8	69.0	79.1	72.1	70.1	76.7	71.0	70.0
	Min....	70.7	71.0	70.7	70.2	70.9	70.3	71.7	70.9	68.8	71.6	70.9	70.0	72.7	70.9	69.9
19	Max....	78.8	75.5	73.6	78.5	75.7	72.3	78.4	73.5	70.0	78.8	73.6	71.4	77.4	72.4	70.7
	Min....	71.7	72.7	72.2	70.8	72.4	71.5	73.1	72.5	69.9	72.9	72.3	71.0	74.5	72.1	70.7
20	Max....	78.5	75.4	73.7	78.0	75.5	72.5	78.3	73.7	70.6	78.4	73.8	72.1	77.2	73.1	71.5
	Min....	72.1	72.9	72.6	71.3	72.6	71.9	73.4	72.9	70.6	73.2	72.8	71.7	74.7	73.0	71.2
21	Max....	80.6	76.0	73.7	81.6	76.6	72.6	80.5	73.9	71.1	80.2	74.0	72.3	77.9	73.6	72.0
	Min....	70.7	72.0	72.1	69.8	71.8	71.7	72.4	72.9	70.7	72.3	72.4	71.9	74.0	73.3	71.7
22	Max....	80.2	75.9	73.7	81.8	76.4	72.6	80.2	73.9	71.4	79.6	73.6	72.6	77.7	74.1	72.3
	Min....	68.6	71.9	71.8	67.5	71.5	71.4	71.3	72.8	70.9	70.9	72.2	71.9	73.6	73.5	72.2
24	Max....	72.8	73.2	73.8	72.4	72.9	73.1	73.4	74.2	71.6	72.6	73.6	72.8	74.9	74.5	72.8
	Min....	70.9	71.7	72.1	69.8	71.3	71.6	71.4	72.7	71.1	70.9	71.9	71.9	73.3	73.9	72.7
25	Max....	75.4	70.9	69.4	75.9	71.0	69.5	74.6	70.3	70.6	73.4	69.2	70.9	72.6	73.1	72.6
	Min....	61.8	66.3	67.9	59.2	65.6	68.2	63.8	69.0	69.0	63.1	67.6	69.4	67.2	71.4	72.0
26	Max....	75.2	70.7	69.2	74.7	70.9	69.3	74.1	69.9	69.1	73.2	68.7	69.6	72.6	71.6	71.5
	Min....	63.6	66.8	67.9	61.5	66.4	68.0	65.4	68.4	68.1	64.4	67.2	68.4	67.8	70.5	70.8
27	Max....	77.3	72.4	70.4	77.0	72.6	69.5	76.6	70.1	68.3	75.4	69.5	68.9	74.9	70.8	70.5
	Min....	66.8	68.6	68.7	64.0	68.3	68.6	67.8	68.9	67.9	66.9	68.1	68.6	69.8	70.3	70.2
28	Max....	70.3	70.0	70.1	69.6	69.6	69.9	70.6	70.5	68.6	70.0	69.4	69.5	71.6	71.0	70.2
	Min....	66.6	68.6	69.1	64.9	68.0	69.0	67.5	69.3	68.3	66.7	68.4	68.9	69.8	70.5	70.1
29	Max....	69.6	68.1	67.7	69.7	68.0	68.0	69.6	68.3	68.1	69.5	67.3	68.4	69.0	70.2	70.1
	Min....	62.4	65.2	66.6	60.4	64.7	66.8	64.1	67.1	66.9	63.8	66.3	67.2	66.4	69.3	69.5
31	Max....	72.9	69.3	67.5	73.2	69.4	67.0	71.9	67.1	65.8	72.0	67.1	66.4	69.4	67.5	68.3
	Min....	64.6	65.4	66.0	63.6	65.2	66.0	65.1	66 1	65.6	65.0	65.6	66.0	66.4	67.2	67.8
Ave.	Max..	78.00	74.07	72.41	77.89	73.90	71.57	77.48	72.73	70.59	76.64	71.83	71.53	76.20	73.48	72.30
	Min..	68.81	70.78	70.99	67.36	70.26	70.57	70.24	71.60	70.08	69.62	70.44	70.84	72.56	72.85	72.00
	Range	9.19	3.29	1.42	10.53	3.64	1.00	7.24	1.13	0.51	7.02	1.39	0.69	3.64	0.63	0.30

TABLE 60.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, SEPTEMBER, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max....	74.2	71.2	69.6	73.1	71.7	69.2	73.8	69.2	66.9	73.9	69.3	67.7	71.6	68.2	67.8
	Min....	68.6	68.6	68.4	67.4	68.4	68.1	68.9	68.5	66.8	68.9	68.1	67.5	69.4	67.9	67.6
2	Max....	69.7	69.5	69.5	69.2	69.4	69.3	70.4	69.6	67.4	70.4	69.3	68.5	70.4	68.9	68.4
	Min....	68.6	68.9	69.0	67.1	68.5	68.7	69.4	69.1	67.3	69.2	68.8	68.4	69.6	68.9	68.0
3	Max....	68.8	67.1	66.8	68.1	67.9	67.2	69.4	67.6	67.2	69.1	66.9	68.1	68.3	68.9	68.6
	Min....	61.4	64.8	65.8	58.8	64.6	66.3	63.2	66.5	66.4	63.0	65.9	66.9	65.7	68.2	68.5
4	Max....	69.1	66.1	65.6	69.9	66.4	66.2	68.5	66.3	66.3	68.0	65.7	66.9	66.8	68.0	68.3
	Min....	59.5	63.0	64.6	56.5	62.7	65.2	61.9	65.4	65.4	61.6	64.6	65.8	64.1	66.9	67.8
5	Max....	69.0	66.1	65.0	70.1	66.4	65.3	68.2	65.3	65.3	67.9	64.6	65.8	66.2	66.9	67.5
	Min....	58.8	62.9	63.6	55.7	62.5	64.2	60.7	64.1	64.5	60.3	63.4	64.8	63.1	66.0	66.9
7	Max....	63.2	63.6	65.1	63.3	63.6	65.4	64.6	65.5	64.9	64.8	64.9	65.6	64.7	66.1	66.3
	Min....	60.3	62.8	63.9	58.9	62.5	64.3	62.0	64.3	64.2	62.0	63.9	64.8	63.7	65.7	66.2
8	Max....	65.6	63.4	62.8	66.1	63.7	63.5	65.8	63.5	64.0	65.3	62.9	64.4	63.9	65.3	66.1
	Min....	55.2	59.7	61.5	53.2	59.3	62.4	58.0	62.3	63.1	58.1	61.6	63.4	60.9	64.4	65.5
9	Max....	67.0	63.9	62.5	66.9	64.1	62.6	66.6	62.5	63.1	66.1	62.0	63.6	64.0	64.2	65.2
	Min....	54.7	59.3	60.8	52.9	58.7	61.5	57.1	61.6	62.1	56.8	60.8	62.5	59.4	63.2	64.6
10	Max....	62.3	61.6	62.4	62.4	61.6	62.8	62.3	62.7	62.6	62.0	61.9	63.0	61.4	63.6	64.5
	Min....	55.9	59.4	60.9	51.7	58.8	61.7	57.8	61.4	61.8	57.4	60.5	62.1	59.4	62.7	64.1
11	Max....	59.7	59.9	61.3	59.4	59.7	61.8	59.8	61.5	61.7	59.9	60.8	62.0	60.0	62.4	63.7
	Min....	57.4	59.3	60.5	56.3	58.9	61.0	58.1	60.5	61.1	58.1	60.0	61.5	59.3	62.0	63.2
12	Max....	61.9	59.9	59.4	62.0	60.0	59.9	61.1	59.5	60.9	61.3	58.8	61.1	59.5	61.5	63.0
	Min....	52.0	56.6	58.1	50.0	56.0	59.0	53.8	58.4	59.8	53.8	57.8	60.0	56.2	60.5	62.4
14	Max....	68.0	63.4	61.8	69.4	64.1	61.7	66.4	61.1	60.0	66.5	61.2	60.9	63.4	60.6	61.7
	Min....	57.4	59.7	60.2	56.9	59.6	60.7	58.4	60.0	59.8	58.5	59.8	60.7	59.8	60.6	61.5
15	Max....	68.9	65.6	63.9	69.7	66.0	63.5	67.7	63.1	61.3	67.9	63.4	62.3	65.6	61.8	61.8
	Min....	62.6	62.9	62.7	62.3	63.0	62.7	62.6	62.3	60.8	62.7	62.1	62.0	62.9	61.5	61.6
16	Max....	73.6	68.6	66.0	73.0	69.2	65.0	72.4	65.1	62.3	71.9	65.4	63.4	69.3	63.1	62.6
	Min....	62.9	64.1	63.8	62.1	63.9	63.6	63.6	63.6	62.0	63.6	63.4	63.1	64.2	62.7	62.2
17	Max....	73.4	68.5	66.1	74.6	68.9	65.3	72.2	65.5	63.4	71.3	65.4	64.6	69.5	64.3	63.5
	Min....	61.1	63.8	64.2	57.3	63.3	64.1	62.4	64.2	63.1	62.0	63.6	64.1	63.7	64.1	63.2
18	Max....	73.9	68.7	66.3	73.1	68.9	65.5	72.4	65.9	64.0	71.5	65.6	65.0	69.7	65.2	64.2
	Min....	61.5	64.1	64.6	59.5	63.7	64.4	62.8	64.7	63.6	62.2	63.9	64.3	64.0	64.8	64.1
19	Max....	74.9	69.2	66.7	75.1	69.4	65.9	73.4	66.3	64.4	72.3	66.0	65.2	70.5	65.8	64.9
	Min....	62.5	64.4	65.1	60.9	64.0	64.9	63.6	65.3	64.1	62.9	64.4	64.6	64.9	65.4	64.6
21	Max....	78.0	72.6	69.7	78.8	72.4	68.2	76.9	69.3	65.7	76.2	69.0	66.6	74.9	67.6	66.2
	Min....	67.5	68.5	67.9	66.4	68.2	67.1	67.9	67.7	65.4	67.2	67.2	66.4	69.9	67.4	65.9
22	Max....	74.1	71.7	70.4	73.8	71.5	69.1	74.0	70.2	66.9	73.6	69.9	68.0	73.6	69.1	67.1
	Min....	70.2	70.2	69.5	69.7	69.9	68.7	70.6	69.5	66.7	70.1	69.1	67.9	71.9	68.8	66.7
23	Max....	65.0	67.5	68.6	64.6	67.0	68.3	65.9	69.1	67.2	65.5	68.4	68.2	69.8	69.5	68.0
	Min....	63.7	65.6	66.4	62.5	65.3	66.3	65.1	67.0	66.6	65.1	66.5	67.1	67.4	68.8	67.8
24	Max....	62.2	61.6	63.4	60.4	61.4	64.1	62.4	64.6	65.5	62.3	63.7	65.9	63.1	67.9	67.9
	Min....	55.3	59.9	62.0	52.8	59.2	62.4	57.7	62.7	64.0	57.7	62.0	64.1	61.6	66.3	67.1
25	Max...	63.4	61.3	61.0	62.3	61.6	61.8	63.2	61.8	63.0	62.9	60.9	63.2	62.4	65.3	66.5
	Min....	53.8	58.1	59.8	51.1	57.7	60.8	55.8	60.7	61.9	56.0	59.7	61.5	59.3	64.1	65.7
26	Max....	64.0	61.5	60.5	64.8	61.8	61.3	63.3	60.9	61.6	63.0	60.0	62.0	62.4	63.6	65.0
	Min....	53.0	57.4	59.0	51.2	56.8	60.0	55.0	59.6	60.8	55.0	58.8	60.3	58.2	62.5	64.1
28	Max....	65.6	62.0	60.9	66.0	62.2	61.5	64.1	60.9	60.8	63.6	60.2	61.3	62.4	62.1	62.9
	Min....	55.3	58.5	59.7	52.7	58.1	60.4	56.6	59.7	60.0	56.3	58.9	59.9	58.8	61.5	62.4
29	Max....	67.5	63.2	61.7	68.2	63.4	61.5	65.6	61.0	60.5	65.4	61.0	61.3	63.8	61.8	62.5
	Min....	56.8	59.5	60.1	54.4	59.1	60.8	57.6	60.0	60.3	57.4	59.5	60.7	59.9	61.5	62.2
30	Max....	66.9	63.4	62.3	67.3	63.6	62.3	65.1	62.0	60.9	65.2	61.5	61.8	64.3	62.1	62.3
	Min....	57.4	60.3	61.0	56.2	59.9	61.5	58.4	60.9	60.6	58.1	60.4	60.6	60.6	61.9	62.1
Ave.	Max..	68.07	65.43	64.59	68.14	65.61	64.56	67.52	64.61	63.76	67.22	64.19	64.48	66.21	65.14	65.26
	Min..	59.75	62.40	63.20	57.86	62.02	63.50	61.12	63.46	63.17	60.92	62.87	63.66	62.99	64.55	64.84
	Range	8.32	3.03	1.39	10.28	3.59	1.06	6.40	1.15	0.59	6.30	1.32	0.82	3.22	0.59	0.41

TABLE 61.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, OCTOBER, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	Max....	66.5	62.9	61.5	66.9	62.6	62.0	64.3	61.4	61.2	64.4	60.9	61.8	63.3	62.3	62.4
	Min....	55.2	58.8	60.0	53.6	58.3	60.6	56.3	59.9	60.4	55.9	59.0	60.9	58.9	61.5	62.2
2	Max....	65.9	62.4	61.1	62.1	62.1	61.5	63.7	60.8	60.9	63.7	60.0	61.5	62.7	62.0	62.4
	Min....	54.7	58.3	59.6	53.3	57.7	60.3	55.7	59.4	59.9	55.4	58.5	60.4	58.4	61.3	62.0
3	Max....	64.2	61.6	60.8	64.3	61.4	61.3	62.6	60.5	60.3	62.7	59.7	60.9	61.9	61.8	62.1
	Min....	55.5	58.3	59.5	54.5	57.9	60.0	56.1	59.2	59.6	55.9	58.4	59.9	58.3	60.9	61.9
5	Max....	68.4	64.7	63.0	68.6	64.5	62.2	66.7	62.1	60.0	66.9	62.1	61.1	65.6	61.4	61.5
	Min....	61.6	61.8	61.6	61.1	61.6	61.5	61.3	61.1	59.8	61.3	60.7	60.8	62.3	61.2	61.4
6	Max....	70.2	66.1	64.2	70.4	65.7	63.4	68.6	63.4	61.4	68.6	63.5	62.3	67.1	62.5	62.0
	Min....	63.0	63.4	63.1	62.4	63.1	62.8	62.9	62.6	61.2	62.9	62.5	62.0	64.1	62.3	61.8
7	Max....	70.8	66.4	64.5	70.8	65.9	63.8	68.9	63.9	62.1	69.1	63.9	63.3	67.4	63.4	62.6
	Min....	62.3	63.4	63.5	61.8	62.9	63.2	62.6	63.3	61.9	62.4	62.8	62.7	64.1	63.1	62.5
8	Max....	67.6	65.6	65.1	66.7	65.4	64.4	67.0	64.8	62.7	67.1	64.7	63.7	66.7	64.1	63.2
	Min....	64.0	64.7	64.6	63.1	64.2	64.1	64.4	64.3	62.6	64.2	64.1	63.7	65.6	64.1	63.1
9	Max....	70.3	66.8	65.1	70.6	66.8	64.3	69.2	65.0	62.9	69.4	65.0	63.9	68.1	64.4	63.7
	Min....	63.1	63.9	63.9	61.1	63.6	63.6	63.6	64.0	62.7	63.7	63.7	63.4	65.0	64.3	63.6
10	Max....	65.6	65.2	65.3	65.3	65.0	64.7	65.7	65.3	63.3	65.7	65.3	64.4	66.6	65.0	64.1
	Min....	64.7	64.7	64.7	63.8	64.4	64.3	65.1	64.8	63.2	65.1	64.7	64.1	66.0	64.8	64.0
12	Max....	57.1	58.8	60.2	55.7	58.4	60.9	58.0	61.1	62.0	58.1	60.5	62.4	59.8	63.6	64.2
	Min....	53.8	57.4	59.2	51.4	56.8	59.8	55.8	59.9	60.7	55.5	59.4	60.9	58.5	62.3	63.6
13	Max....	54.0	56.9	58.4	52.1	56.6	59.2	55.3	58.9	60.0	55.6	58.5	60.4	58.1	61.8	63.1
	Min....	52.9	55.7	57.4	51.0	55.4	58.1	54.0	57.8	59.1	54.1	57.4	59.5	56.9	60.9	62.6
14	Max....	52.6	53.6	55.4	51.1	53.5	56.8	52.7	56.0	58.0	52.9	55.5	58.3	54.7	59.8	61.8
	Min....	50.1	53.0	54.8	48.9	52.8	55.9	51.2	55.1	57.1	51.4	54.8	57.4	54.4	58.7	61.2
15	Max....	57.4	56.4	56.2	57.0	56.7	56.8	56.9	55.7	56.4	57.2	55.8	56.6	56.5	57.9	60.3
	Min....	52.9	53.8	54.9	51.2	53.8	55.8	52.9	54.8	56.1	53.1	54.6	56.3	54.3	57.4	59.6
16	Max....	58.6	57.7	57.4	57.4	57.8	57.7	58.4	56.9	56.4	58.5	57.0	57.1	57.5	57.5	59.0
	Min....	56.4	56.6	57.0	55.5	56.9	57.5	56.4	56.5	56.3	56.7	56.7	57.0	56.8	57.2	58.5
17	Max....	58.1	57.8	57.6	57.5	57.9	57.8	58.1	57.1	56.9	58.4	57.1	57.7	57.5	57.4	58.3
	Min....	52.9	55.8	56.6	51.7	55.5	57.1	54.1	56.4	56.8	54.2	56.2	57.2	56.3	57.2	58.1
19	Max....	58.0	56.9	56.5	58.9	57.3	57.4	57.7	56.5	56.9	57.7	56.3	57.4	56.1	57.0	58.3
	Min....	50.4	54.4	55.4	49.3	53.8	56.2	52.0	55.4	56.3	52.0	54.9	56.7	53.5	56.5	57.9
20	Max....	60.6	57.9	57.0	61.2	58.8	57.1	59.7	56.4	56.5	60.0	56.5	56.6	57.5	57.2	57.9
	Min....	51.6	54.5	55.4	50.5	54.3	56.1	52.6	55.4	56.0	52.9	54.9	56.4	54.0	56.1	57.6
21	Max....	61.6	59.1	58.0	62.7	59.9	58.0	61.0	57.3	56.5	61.3	57.4	57.4	58.7	56.8	57.6
	Min....	53.0	55.5	56.2	52.1	55.5	57.0	54.2	56.1	56.2	54.3	56.0	56.9	55.1	56.5	57.4
22	Max....	61.7	59.0	57.9	61.7	59.6	58.1	60.7	57.6	57.0	60.9	57.6	57.9	58.4	57.2	57.8
	Min....	53.4	55.9	56.8	52.3	55.8	57.3	54.6	56.7	56.7	54.8	56.6	57.4	55.5	56.9	57.6
23	Max....	60.0	57.8	57.6	60.3	58.4	58.1	59.2	57.4	57.1	59.5	57.4	58.0	57.6	57.5	57.9
	Min....	52.2	55.1	56.4	51.2	54.8	57.0	53.8	56.4	56.6	53.9	56.2	57.2	54.8	56.8	57.7
24	Max....	53.9	55.9	57.1	53.1	56.1	57.6	54.4	56.5	56.9	54.8	56.9	57.6	55.9	57.2	57.9
	Min....	52.3	54.0	56.0	51.9	54.8	56.8	53.4	55.9	56.6	53.7	55.8	57.2	54.8	56.9	57.7
26	Max....	49.1	50.0	51.6	49.7	50.1	53.2	48.5	51.9	53.8	49.3	51.6	53.8	50.0	54.2	56.8
	Min....	46.8	49.0	51.0	47.1	46.6	52.5	48.0	50.9	53.2	48.8	50.8	53.2	49.7	53.5	56.2
27	Max....	43.3	44.1	48.8	45.3	47.6	49.8	43.8	48.9	52.2	44.1	49.4	51.3	48.5	52.8	55.6
	Min....	40.2	42.4	47.1	43.7	46.3	48.4	40.4	47.7	51.0	41.1	47.2	50.5	45.4	51.6	54.8
28	Max....	45.9	47.0	48.1	45.5	47.3	48.6	45.2	48.6	49.9	45.5	45.9	49.5	45.5	50.5	53.9
	Min....	40.6	43.9	46.2	38.8	43.9	48.2	40.4	45.7	49.4	41.0	45.2	48.8	42.9	49.4	53.2
29	Max....	45.5	47.3	48.6	44.1	48.4	48.8	45.7	47.6	48.8	47.3	47.6	48.9	46.2	48.9	52.4
	Min....	44.8	46.4	47.5	43.4	46.4	47.1	45.5	46.9	48.7	45.3	47.2	48.3	45.4	48.6	51.8
30	Max....	48.2	47.5	47.6	48.4	47.6	48.5	47.2	46.3	49.8	47.6	47.2	48.9	45.7	48.6	51.4
	Min....	40.4	44.2	47.1	39.8	44.3	47.6	41.3	45.6	48.5	41.4	45.3	48.1	43.3	47.7	50.9
31	Max....	50.2	48.6	48.9	50.7	49.1	48.9	48.8	46.9	48.3	49.6	47.2	48.4	46.4	47.7	50.5
	Min....	41.0	44.8	46.4	40.7	44.9	47.5	43.6	45.9	48.0	43.2	45.6	48.2	43.5	47.5	50.2
Ave.	Max..	58.71	57.76	57.74	58.60	57.80	57.81	58.08	57.22	57.34	58.37	57.06	57.97	57.78	58.17	59.21
	Min..	52.96	55.18	56.36	52.05	55.05	56.90	53.79	56.21	56.84	53.86	55.90	57.23	55.52	57.42	58.86
	Range	5.75	2.58	1.38	6.55	2.75	0.91	4.29	1.01	0.50	4.51	1.16	0.74	2.26	0.75	0.35

TABLE 62.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND, NOVEMBER, 1914.

Date— Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2 Max....	50.8	50.3	50.3	50.1	50.5	51.2	50.0	49.6	49.8	50.7	49.6	50.6	48.8	48.8	50.3
Min....	45.9	48.5	49.6	45.1	48.5	50.6	47.0	49.0	49.7	47.1	48.8	50.3	46.9	48.7	50.3
3 Max....	51.7	50.9	50.4	50.9	51.4	50.9	51.3	49.7	49.8	51.6	49.8	50.2	49.4	49.1	50.7
Min....	47.0	48.2	49.3	44.6	48.5	49.7	46.6	48.8	49.7	47.2	48.8	49.8	47.5	48.9	50.6
4 Max....	48.5	49.6	50.2	47.5	50.1	51.1	49.4	49.9	50.2	49.8	49.8	50.8	48.9	49.6	50.9
Min....	46.4	48.5	49.8	45.4	48.8	50.6	47.5	49.5	50.0	47.7	49.3	50.6	47.9	49.5	50.8
5 Max....	45.0	47.0	48.6	41.8	46.9	49.9	45.1	48.8	49.7	45.4	48.6	50.5	47.0	49.7	51.1
Min....	43.6	46.3	47.8	41.2	46.2	48.9	45.1	48.1	49.5	45.1	47.6	49.8	46.2	49.2	51.1
6 Max....	45.5	46.0	46.7	44.7	46.2	48.1	45.9	46.9	48.4	46.2	46.6	49.3	45.1	48.8	51.0
Min....	40.7	43.9	45.9	40.5	43.6	47.3	42.1	46.1	45.4	42.6	45.8	48.2	43.6	48.0	50.6
7 Max....	49.4	48.0	47.5	49.5	48.3	48.0	48.9	46.6	47.9	49.3	47.1	48.1	46.5	47.8	50.3
Min....	42.7	44.7	45.9	40.8	44.7	47.1	43.3	45.8	47.5	43.4	45.7	47.8	44.1	47.3	49.8
9 Max....	41.6	41.7	44.4	40.0	43.4	46.1	41.5	44.7	47.4	41.7	45.4	47.5	43.7	47.5	49.5
Min....	37.1	40.7	43.3	35.6	40.6	45.0	38.3	43.5	46.2	38.8	43.3	46.0	41.2	46.1	48.8
10 Max....	43.0	43.1	43.6	41.2	43.4	45.0	42.2	43.2	45.4	42.7	43.3	45.6	41.6	45.5	48.6
Min....	39.4	41.7	43.2	37.2	41.6	44.7	39.3	42.9	45.2	40.4	42.8	45.4	40.4	45.1	48.0
11 Max....	43.0	43.1	43.4	41.1	43.3	45.0	42.3	43.1	45.1	43.1	43.2	45.4	41.3	45.4	47.6
Min....	38.0	41.0	43.0	39.3	41.2	44.5	39.3	42.6	44.8	40.3	42.5	45.1	40.3	44.4	47.3
12 Max....	40.3	41.6	42.9	36.6	41.6	44.4	40.3	42.8	44.8	40.7	42.7	45.1	40.5	44.1	47.0
Min....	38.6	40.8	42.4	35.8	40.8	44.0	39.1	42.3	44.4	39.4	42.1	44.4	40.0	43.8	46.7
13 Max....	43.0	43.1	43.9	39.4	43.6	45.1	41.8	43.2	44.4	42.5	43.3	44.7	41.7	43.5	46.4
Min....	41.3	42.6	43.1	37.6	42.8	44.4	41.8	42.5	44.1	42.3	42.5	44.4	40.8	43.5	46.2
14 Max....	41.9	42.4	42.9	39.7	42.5	44.4	41.5	42.6	44.4	42.1	42.5	44.8	40.6	43.5	46.1
Min....	37.7	40.4	42.3	36.9	40.4	43.8	38.9	41.9	44.2	39.4	41.8	44.1	39.5	43.2	45.8
16 Max....	38.9	42.6	44.4	38.6	42.6	45.5	40.0	43.9	44.8	40.5	43.9	45.4	42.4	43.9	45.8
Min....	37.3	40.7	42.6	36.5	40.6	44.1	38.1	42.4	44.6	38.6	42.3	44.9	39.5	43.6	45.7
17 Max....	36.3	39.4	41.3	35.5	39.4	42.9	37.0	41.4	44.2	37.1	41.1	43.5	39.3	43.4	45.8
Min....	35.4	38.5	40.3	34.8	38.7	42.1	36.1	40.6	43.4	36.3	40.4	43.1	38.6	42.8	45.6
18 Max...	33.9	37.4	39.4	33.4	37.5	41.2	34.9	39.7	42.5	35.0	39.0	42.3	37.5	42.3	45.4
Min....	33.5	36.6	38.5	33.1	36.8	40.5	34.4	38.7	42.3	34.5	38.2	41.4	36.8	41.6	45.1
19 Max....	33.9	36.6	38.2	33.5	36.8	40.0	34.4	38.3	41.3	34.6	37.9	40.9	36.2	41.0	44.5
Min....	33.7	36.4	38.0	33.4	36.7	39.8	34.3	37.9	41.0	34.5	37.6	40.6	36.2	40.7	44.2
20 Max....	33.9	36.4	37.9	33.3	36.5	39.7	34.2	37.8	40.6	34.6	37.4	40.3	35.8	40.2	43.5
Min....	33.8	36.3	37.7	33.2	36.3	39.4	34.0	37.5	40.4	34.4	37.2	40.0	35.6	39.8	43.3
21 Max....	33.8	36.3	37.7	33.2	36.3	39.3	34.0	37.4	39.9	34.5	37.2	39.8	35.2	39.5	42.8
Min....	33.6	36.1	37.4	33.0	36.0	39.1	33.9	37.2	39.7	34.3	36.9	39.5	35.1	39.3	42.4
23 Max....	32.9	35.7	37.3	32.2	35.8	38.9	33.9	37.0	39.4	34.3	36.9	39.3	35.0	38.5	41.7
Min....	32.3	35.1	36.7	31.6	35.1	38.3	33.4	36.7	39.1	33.8	36.5	39.0	34.1	38.1	41.3
24 Max....	32.2	34.8	36.4	32.0	34.8	38.0	33.4	36.5	38.9	33.7	36.4	38.8	34.4	37.9	41.1
Min....	32.1	34.6	36.3	31.3	34.8	37.9	33.3	36.4	38.5	33.5	36.2	38.4	34.2	37.8	40.8
25 Max....	32.7	34.9	36.3	32.3	35.0	37.9	33.4	36.3	38.4	33.9	36.2	38.4	31.3	37.7	40.7
Min....	32.4	34.8	36.2	32.2	34.8	37.7	33.3	36.1	38.2	33.8	36.1	38.2	34.2	37.4	40.6
26 Max....	41.9	39.2	38.1	41.6	39.0	38.7	39.3	36.8	38.2	40.9	37.6	38.3	34.2	37.4	40.5
Min....	33.2	34.9	36.3	32.6	35.2	37.7	33.4	36.0	38.0	34.0	36.2	38.1	34.0	37.2	40.1
27 Max....	38.5	40.2	40.4	38.0	40.4	40.9	38.7	39.2	39.7	39.7	39.9	40.5	35.2	37.3	40.2
Min....	37.4	39.1	39.9	37.3	39.4	40.8	37.9	38.9	38.9	38.9	39.8	39.9	34.4	37.3	40.0
28 Max....	35.2	37.9	39.4	34.6	37.9	40.4	35.9	38.8	40.2	36.4	39.2	40.9	35.3	37.6	40.4
Min....	34.2	37.2	38.3	33.9	37.2	39.6	34.8	37.9	39.9	35.2	37.9	40.2	35.0	37.4	40.3
30 Max....	46.3	44.1	42.7	46.7	44.5	42.8	44.9	41.5	40.4	45.8	41.9	41.1	41.1	38.3	40.4
Min....	42.7	41.2	40.7	42.6	41.6	41.2	41.3	39.4	39.6	42.0	39.9	40.0	37.9	37.7	40.3
Ave. Max..	40.56	41.69	42.57	39.50	41.90	43.82	40.57	42.23	43.84	41.08	42.26	44.09	40.44	43.13	45.85
Min..	38.00	40.36	41.78	37.06	40.44	43.15	38.68	41.55	43.37	39.10	41.45	43.57	39.36	42.74	45.43
Range	2.56	1.33	0.79	2.44	1.46	0.67	1.89	0.68	0.47	1.98	0.81	0.52	1.08	0.39	0.42

BEGINNING WITH FOURTH YEAR.

TABLE 63.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, DECEMBER, 1914.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
2	Max....	47.4	47.3	46.9	46.2	47.1	47.1	46.9	46.6	45.4	47.3	46.6	46.2	46.3	45.4	45.5
	Min....	44.6	45.4	46.1	44.4	45.2	46.1	44.9	45.4	45.2	45.3	45.8	46.1	45.4	45.4	45.3
3	Max....	42.5	41.8	41.4	39.7	39.8	40.4	40.4	41.1	41.5	42.4	41.4	42.1	40.9	42.2	44.1
	Min....	36.5	38.4	40.4	36.2	37.8	40.0	37.4	40.3	40.8	37.4	40.3	41.5	39.6	41.2	42.9
4	Max....	37.9	37.7	38.1	37.4	37.4	38.1	37.3	37.7	38.1	37.5	37.6	38.7	37.4	38.8	41.1
	Min....	33.4	35.1	37.0	33.7	35.0	36.8	33.9	36.7	37.5	34.5	36.6	38.0	36.7	38.2	40.4
5	Max....	38.6	38.0	38.4	38.1	38.1	38.8	37.5	38.0	37.9	38.0	38.0	38.4	37.7	38.2	39.4
	Min....	34.0	35.2	36.4	34.0	35.0	36.3	34.1	35.9	36.8	35.7	35.9	37.1	35.7	37.3	39.1
7	Max....	34.8	35.1	35.5	34.0	34.7	35.4	34.1	34.9	35.4	34.7	35.0	35.9	35.0	36.3	37.9
	Min....	33.2	34.2	35.2	33.1	34.0	35.3	33.4	34.8	35.3	33.8	34.9	35.8	34.8	35.9	37.5
8	Max....	33.0	34.0	34.7	32.8	33.6	34.5	32.8	33.9	34.4	33.4	33.9	34.7	33.8	35.0	37.0
	Min....	32.1	33.3	34.1	32.3	33.4	34.3	32.4	33.8	34.2	32.6	33.6	34.5	33.5	34.7	36.5
9	Max....	32.4	33.4	34.2	32.4	33.4	34.3	32.4	33.7	34.1	32.8	33.5	34.4	33.5	34.4	36.3
	Min....	32.3	33.2	34.0	31.9	33.2	34.1	32.4	33.6	34.0	32.5	33.3	34.2	33.3	34.2	35.9
10	Max....	32.2	33.2	33.9	32.1	33.0	33.8	32.4	33.5	33.9	32.4	33.1	33.9	33.1	33.9	35.7
	Min....	31.9	33.0	33.8	31.4	32.8	33.7	32.4	33.5	33.7	32.2	33.0	33.8	33.1	33.9	35.4
11	Max....	31.5	32.6	33.5	30.4	32.1	33.2	32.2	33.4	33.8	31.4	32.7	33.5	33.0	33.8	35.5
	Min....	29.4	32.2	33.1	26.1	30.6	32.4	32.0	33.1	33.4	31.0	32.2	33.2	32.4	33.4	35.0
12	Max....	30.7	31.9	32.6	29.7	30.7	32.1	31.6	32.9	33.2	30.5	31.6	32.6	32.4	33.4	34.9
	Min....	29.8	31.4	32.5	27.5	29.7	31.8	31.5	32.8	33.0	29.7	31.5	32.4	32.2	33.2	34.6
14	Max....	31.2	32.2	32.9	27.0	29.6	32.0	31.7	32.9	33.4	31.5	32.2	32.8	32.4	33.1	34.5
	Min....	28.4	32.1	32.6	21.8	26.3	30.0	30.0	32.6	33.0	29.3	31.5	32.6	32.1	32.9	34.4
15	Max....	29.3	30.5	31.5	25.1	27.0	28.9	30.4	32.2	32.7	29.0	30.3	32.0	31.5	32.8	34.2
	Min....	27.7	29.7	31.1	21.8	24.6	27.4	29.9	32.0	32.4	27.4	29.8	31.4	31.1	32.6	34.1
16	Max....	29.2	30.2	31.2	23.4	26.1	28.4	30.1	31.9	32.6	28.5	29.9	31.4	31.3	32.5	34.0
	Min....	27.9	29.8	30.9	20.4	24.1	26.9	29.6	31.6	32.3	27.6	29.5	30.9	31.1	32.4	33.9
17	Max....	29.4	30.2	30.8	25.3	26.4	27.8	30.0	31.5	33.4	28.8	29.6	30.9	31.3	32.4	33.8
	Min....	27.6	29.7	30.6	21.0	24.6	26.9	29.3	31.4	32.1	27.6	29.4	30.8	30.8	32.3	33.6
18	Max....	30.0	30.8	31.1	27.5	28.8	29.7	30.2	31.3	32.0	29.5	30.0	30.7	31.4	32.2	33.6
	Min....	27.5	28.9	30.0	21.5	23.3	25.3	29.0	31.0	31.6	27.3	28.8	30.3	30.6	32.0	33.4
19	Max....	31.2	31.8	32.0	30.1	31.2	31.6	31.0	31.7	31.8	30.8	31.1	31.4	31.9	32.0	33.4
	Min....	30.9	31.4	31.6	29.6	30.6	30.9	30.7	31.5	31.6	30.4	30.6	31.1	31.8	32.0	33.3
21	Max....	31.4	31.9	32.1	29.4	31.0	31.5	31.0	31.8	31.9	31.1	31.3	31.7	31.9	32.1	33.3
	Min....	31.0	31.5	31.9	29.3	30.4	31.0	30.9	31.7	31.7	30.9	31.1	31.6	31.6	31.9	33.2
22	Max....	31.2	31.9	32.1	29.3	30.1	30.9	30.8	31.8	32.0	31.1	31.4	32.0	31.7	32.2	33.3
	Min....	31.1	31.6	32.0	28.8	29.9	30.7	30.6	31.6	31.8	30.9	31.1	31.8	31.5	32.0	33.2
23	Max....	31.3	31.9	32.2	29.3	30.5	31.2	30.8	31.7	32.0	31.0	31.4	31.9	31.6	32.1	33.3
	Min....	31.2	31.8	32.1	29.0	30.1	31.0	30.6	31.5	31.8	30.8	31.3	31.8	31.4	32.0	33.1
21	Max....	31.5	32.1	32.3	29.2	30.9	31.6	31.0	31.7	31.9	31.2	31.4	32.0	31.7	32.1	33.4
	Min....	31.2	31.9	32.2	28.6	30.3	31.0	30.7	31.6	31.7	30.9	31.3	31.8	31.5	32.0	33.1
26	Max....	30.8	31.6	32.2	27.4	28.9	30.3	30.4	31.8	32.9	30.5	31.4	32.1	31.2	32.2	33.4
	Min....	30.2	31.1	31.7	26.1	28.1	29.6	29.8	31.1	31.5	30.0	30.7	31.4	30.6	31.6	32.9
28	Max....	31.5	32.0	32.1	29.9	31.3	31.6	30.8	31.5	31.6	31.2	31.3	31.7	31.6	31.7	32.7
	Min....	31.4	31.9	32.1	29.0	30.7	31.3	30.7	31.5	31.5	31.0	31.3	31.6	31.4	31.6	32.6
29	Max....	31.9	32.3	32.3	31.0	31.8	32.1	31.2	31.7	31.7	31.6	31.5	31.9	32.0	31.8	32.6
	Min....	31.7	32.1	32.2	30.5	31.6	31.9	31.0	31.6	31.6	31.4	31.5	31.8	31.8	31.6	32.6
30	Max....	32.2	32.4	32.4	31.6	32.2	32.4	31.4	32.0	31.9	31.9	31.9	32.1	32.1	31.9	32.8
	Min....	32.0	32.3	32.3	31.5	32.1	32.3	31.3	31.9	31.7	31.7	31.8	32.0	32.0	31.8	32.6
31	Max....	32.1	32.5	32.5	30.9	31.9	32.4	31.4	32.2	32.0	31.8	32.1	32.3	32.0	32.0	32.9
	Min....	31.8	32.3	32.4	30.5	31.4	32.0	31.2	32.0	31.9	31.5	31.8	32.1	31.5	31.9	32.7
Ave.	Max..	33.02	33.57	33.96	31.58	32.31	33.36	32.79	33.74	34.06	32.80	33.21	33.89	33.55	34.18	35.55
	Min..	31.55	32.78	33.53	29.20	30.99	32.76	31.99	33.38	33.69	31.74	32.75	33.59	33.10	33.92	35.25
	Range	1.47	0.79	0.43	2.38	1.32	0.60	0.80	0.36	0.37	1.06	0.46	0.30	0.45	0.26	0.30

TABLE 64.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JANUARY, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
2	Max....	32.2	32.4	32.5	31.5	32.2	32.4	31.4	32.1	31.9	32.0	32.0	32.3	31.9	31.9	32.8
	Min....	32.1	32.4	32.4	31.4	32.0	32.3	31.3	32.0	31.9	31.9	31.9	32.1	31.9	31.7	32.6
4	Max....	31.8	32.3	32.5	31.1	31.6	32.2	31.0	31.9	31.9	31.4	31.8	32.2	31.3	31.7	32.6
	Min....	31.7	32.3	32.3	30.7	31.5	32.1	30.9	31.6	31.5	31.4	31.3	32.0	31.3	31.4	32.4
5	Max....	32.1	32.3	32.4	31.5	32.1	32.3	31.2	31.2	31.7	31.7	31.8	32.2	31.7	31.6	32.4
	Min....	31.9	32.3	32.3	31.4	31.9	32.2	31.1	31.6	31.5	31.6	31.0	32.0	31.5	31.5	32.3
6	Max....	32.2	32.3	32.4	31.9	32.2	32.3	31.4	32.1	31.7	32.4	32.3	32.3	32.2	31.8	32.4
	Min....	32.1	32.3	32.3	31.7	32.1	32.3	31.3	31.8	31.6	31.9	31.8	32.1	31.9	31.5	32.3
7	Max....	32.3	32.5	32.5	32.1	32.4	32.4	31.8	32.1	31.9	32.5	32.3	32.3	32.4	32.0	32.4
	Min....	32.2	32.4	32.4	32.1	32.3	32.4	31.8	32.1	31.8	32.4	32.3	32.3	32.3	31.9	32.3
8	Max....	32.4	32.6	32.7	32.2	32.4	32.5	32.0	32.2	32.0	32.5	32.4	32.3	32.3	32.1	32.5
	Min....	32.3	32.4	32.6	32.1	32.3	32.4	31.9	32.2	31.9	32.5	32.3	32.3	32.3	32.0	32.4
9	Max....	32.4	32.6	32.9	31.9	32.5	32.6	32.0	32.3	32.1	32.6	32.4	32.4	32.5	32.1	32.6
	Min....	32.3	32.6	32.8	31.8	32.3	32.5	31.8	32.2	32.0	32.5	32.4	32.3	32.4	32.0	32.5
11	Max....	32.2	32.6	32.8	31.9	32.3	32.6	31.5	32.2	32.0	32.2	32.3	32.3	32.3	32.0	32.5
	Min....	32.2	32.5	32.8	31.8	32.2	32.6	31.5	32.1	32.0	32.1	32.2	32.3	32.3	31.9	32.4
12	Max....	32.3	32.8	33.1	32.0	32.5	32.7	31.8	32.3	32.1	32.4	32.3	32.5	32.3	32.0	32.6
	Min....	32.3	32.7	33.0	31.9	32.3	32.6	31.7	32.2	32.0	32.3	32.3	32.4	32.3	31.9	32.5
13	Max....	32.3	32.9	33.1	32.1	32.4	32.8	31.9	32.2	32.1	32.3	32.3	32.5	32.3	32.1	32.6
	Min....	32.3	32.7	33.0	31.8	32.3	32.7	31.6	32.2	32.0	32.3	32.3	32.4	32.3	32.0	32.5
14	Max....	32.3	32.8	33.1	31.8	32.4	32.9	31.5	32.3	32.1	32.3	32.3	32.6	32.3	31.9	32.6
	Min....	32.3	32.7	33.0	31.6	32.3	32.8	31.4	32.1	32.0	32.1	32.3	32.5	32.3	31.8	32.5
15	Max....	32.3	32.9	33.2	31.8	32.4	32.9	31.7	32.2	32.1	32.3	32.3	32.7	32.3	32.0	32.6
	Min....	32.3	32.7	33.1	31.3	32.3	32.8	31.5	32.1	32.0	32.2	32.2	32.5	32.3	31.9	32.5
16	Max....	32.4	32.9	33.2	31.1	32.4	33.0	31.6	32.2	32.1	32.3	32.3	32.6	32.3	32.1	32.6
	Min....	32.3	32.8	33.1	30.9	32.3	32.9	31.4	32.1	32.0	32.1	32.3	32.6	32.3	31.9	32.5
18	Max....	32.4	32.9	33.2	32.2	32.6	32.9	32.0	32.3	32.2	32.5	32.4	32.7	32.3	32.1	32.5
	Min....	32.3	32.8	33.1	32.0	32.5	32.8	31.9	32.3	32.1	32.4	32.4	32.6	32.3	32.0	32.4
19	Max....	32.4	32.9	33.2	32.1	32.6	33.1	31.9	32.3	32.2	32.3	32.4	32.8	32.3	32.0	32.5
	Min....	32.4	32.8	33.1	32.1	32.5	32.9	31.9	32.2	32.1	32.3	32.4	32.7	32.3	31.9	32.4
20	Max....	32.3	32.9	33.2	32.1	32.6	33.1	31.9	32.4	32.3	32.2	32.4	32.9	32.4	32.1	32.6
	Min....	32.3	32.8	33.1	32.1	32.4	32.8	31.6	32.3	32.2	32.2	32.4	32.8	32.3	31.9	32.4
21	Max....	32.3	32.9	33.2	31.7	32.3	33.1	31.6	32.3	32.3	32.2	32.4	32.9	32.4	32.1	32.7
	Min....	32.3	32.6	33.1	31.4	32.2	32.7	31.5	32.3	32.2	32.1	32.2	32.9	32.3	32.0	32.6
22	Max....	32.2	32.9	33.3	30.4	31.4	32.7	31.5	32.4	32.4	31.9	32.4	33.0	32.5	32.2	32.9
	Min....	32.1	32.8	33.1	30.3	31.3	32.6	31.3	32.3	32.3	31.8	32.3	32.9	32.4	32.1	32.7
23	Max....	32.2	32.6	33.1	30.6	31.0	32.4	31.4	32.3	32.3	32.1	32.3	32.7	32.4	32.2	32.8
	Min....	32.0	32.5	32.9	29.9	30.8	32.2	31.3	32.2	32.3	32.0	32.2	32.6	32.3	32.0	32.7
25	Max....	31.5	32.1	32.5	29.8	30.4	31.1	31.1	32.1	32.2	31.6	32.0	32.6	32.1	32.1	32.8
	Min....	31.1	31.8	32.4	28.8	29.7	31.0	30.9	32.0	32.1	31.4	31.9	32.4	31.9	32.0	32.6
26	Max....	31.2	32.0	32.5	29.2	30.0	31.0	30.9	32.1	32.3	31.4	32.0	32.6	32.1	32.2	32.9
	Min....	30.7	31.5	32.3	28.0	29.6	30.4	30.5	31.9	32.0	31.1	31.5	32.3	31.7	32.0	32.6
27	Max....	31.2	31.6	32.2	28.9	29.6	30.5	30.9	32.0	32.2	31.3	31.8	32.5	31.8	32.1	32.9
	Min....	30.4	31.2	32.0	26.7	28.0	29.8	30.4	31.8	32.0	31.0	31.5	32.3	31.5	31.8	32.7
28	Max....	30.7	31.4	32.3	28.0	29.0	30.4	30.6	32.0	32.2	31.2	31.9	32.6	32.0	32.2	33.1
	Min....	30.2	31.0	31.8	27.0	28.1	29.7	30.3	31.5	31.8	30.7	31.4	32.3	31.4	31.8	32.8
29	Max....	30.5	31.2	31.8	27.8	28.7	29.8	30.4	31.6	32.0	30.8	31.4	32.4	31.5	32.0	32.9
	Min....	30.2	30.8	31.5	26.9	28.0	29.4	30.3	31.4	31.8	30.6	31.2	32.2	31.4	31.8	32.7
30	Max....	29.6	30.2	31.3	25.9	26.8	28.1	29.8	31.4	32.1	30.4	31.4	32.4	31.1	32.0	33.2
	Min....	28.6	29.5	30.5	23.9	25.1	27.1	29.2	30.8	31.4	29.8	30.5	32.0	30.5	31.3	32.6
Ave.	**Max..**	31.91	32.38	32.73	30.86	31.47	32.07	31.39	32.13	32.10	31.95	32.15	32.53	32.12	32.03	32.68
	Min..	31.72	32.20	32.56	30.38	31.13	31.84	31.21	31.97	31.94	31.79	31.94	32.39	31.99	31.84	32.52
	Range	0.19	0.18	0.17	0.48	0.34	0.23	0.18	0.16	0.16	0.16	0.21	0.14	0.13	0.19	0.16

TABLE 65.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, FEBRUARY, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2"	4"	6"	2"	4"	6"	2"	4"	6"	2"	4"	6"	2"	4"	6"
1	Max....	32.2	32.2	32.3	32.2	32.4	32.5	31.4	31.8	31.6	32.2	32.0	32.2	32.2	31.9	32.5
	Min....	32.0	32.1	32.1	32.1	32.3	32.4	31.1	31.5	31.4	31.9	31.6	32.0	32.1	31.6	32.4
2	Max....	32.3	32.4	32.4	32.3	32.4	32.6	31.6	32.1	31.7	32.1	32.1	32.3	32.3	32.0	32.5
	Min....	32.3	32.4	32.4	32.2	32.4	32.5	31.5	32.0	31.6	31.5	31.9	32.3	32.3	31.9	32.4
3	Max....	32.3	32.5	32.4	32.3	32.5	32.6	31.4	32.1	31.7	31.1	31.4	32.4	32.4	32.0	32.5
	Min....	31.8	32.3	32.4	32.2	32.4	32.4	31.2	32.0	31.7	31.0	31.4	32.2	32.3	31.9	32.4
4	Max....	31.3	31.9	32.3	32.3	32.5	32.6	31.1	32.0	31.8	30.9	31.3	32.1	32.4	32.0	32.5
	Min...	30.9	31.6	32.1	32.1	32.4	32.4	31.0	31.6	31.6	30.7	31.1	31.9	32.2	31.7	32.4
5	Max....	32.1	32.3	32.4	32.2	32.4	32.4	31.4	32.0	31.6	32.1	31.9	32.1	32.3	31.9	32.4
	Min....	31.9	32.3	32.3	32.0	32.3	32.4	31.1	31.7	31.5	31.4	31.4	32.0	32.1	31.8	32.3
6	Max....	32.3	32.4	32.4	32.2	32.5	32.5	31.7	32.1	31.8	32.3	32.2	32.3	32.3	31.9	32.5
	Min....	32.2	32.3	32.4	32.1	32.3	32.4	31.6	32.0	31.6	32.3	32.1	32.2	32.3	31.9	32.5
8	Max....	32.4	32.5	32.5	32.3	32.5	32.8	31.6	32.2	31.9	32.3	32.3	32.4	32.4	32.0	32.6
	Min....	32.2	32.4	32.5	32.2	32.4	32.6	31.5	32.1	31.7	32.1	32.1	32.4	32.2	31.9	32.4
9	Max....	32.0	32.4	32.6	32.2	32.4	32.8	31.3	32.1	31.9	31.9	32.1	32.4	32.4	32.0	32.6
	Min....	31.7	32.3	32.4	32.1	32.4	32.6	31.0	32.0	31.7	31.6	32.0	32.3	32.2	31.9	32.4
10	Max....	31.6	32.1	32.6	32.3	32.6	33.0	30.9	32.0	32.1	31.4	32.1	32.6	32.4	32.1	32.6
	Min....	31.0	31.9	32.3	32.1	32.3	32.7	30.5	31.6	31.6	30.9	31.5	32.2	32.2	31.9	32.3
11	Max....	32.1	32.3	32.3	32.0	32.4	32.7	31.3	31.8	31.5	32.1	32.0	32.3	32.2	31.8	32.4
	Min....	31.9	32.2	32.3	32.0	32.3	32.6	31.0	31.6	31.5	31.6	31.9	32.2	32.1	31.7	32.3
12	Max....	32.1	32.3	32.4	32.1	32.4	32.8	31.5	32.0	31.6	32.2	32.1	32.3	32.3	31.9	32.4
	Min....	32.1	32.3	32.3	32.0	32.3	32.6	31.4	31.9	31.5	32.2	32.1	32.3	32.2	31.8	32.3
13	Max....	32.2	32.4	32.4	32.1	32.5	32.8	31.6	32.1	31.8	32.3	32.2	32.4	32.3	31.9	32.5
	Min....	32.1	32.4	32.4	32.0	32.4	32.7	31.6	32.0	31.6	32.3	32.2	32.3	32.2	31.7	32.4
15	Max....	32.2	32.4	32.6	32.2	32.5	32.9	31.8	32.1	31.8	32.4	32.4	32.4	32.3	31.9	32.4
	Min....	32.2	32.3	32.6	32.1	32.5	32.8	31.8	32.1	31.7	32.4	32.3	32.4	32.3	31.9	32.4
16	Max....	31.9	32.4	32.7	32.0	32.5	32.9	31.2	32.2	31.9	31.8	32.2	32.6	32.3	31.9	32.5
	Min....	31.2	32.3	32.6	31.5	32.4	32.8	30.8	32.0	31.8	31.4	32.2	32.5	31.8	31.9	32.4
17	Max....	32.1	32.3	32.2	32.1	32.3	32.5	31.1	31.4	32.0	32.1	31.8	32.5	31.8	31.4	32.5
	Min....	27.0	29.4	32.1	25.6	29.0	32.3	27.3	31.0	31.5	28.5	31.1	32.2	28.2	31.3	32.3
18	Max....	32.1	32.3	32.4	32.0	32.2	32.6	31.4	31.4	31.8	32.1	31.9	32.4	31.8	31.4	32.5
	Min....	28.0	31.2	32.3	28.1	31.4	32.4	27.4	30.8	31.3	29.3	31.4	32.2	28.0	30.9	32.3
19	Max....	32.0	32.0	32.4	31.9	32.1	32.7	30.5	31.4	31.6	31.1	31.4	32.4	31.0	30.9	32.4
	Min....	28.0	31.2	32.2	28.1	31.5	32.4	28.4	31.0	31.3	29.5	31.3	32.1	27.8	30.4	32.3
20	Max....	33.3	32.9	32.4	34.3	34.4	34.1	31.7	31.9	31.7	32.3	32.1	32.4	31.9	31.6	32.4
	Min....	30.5	32.3	32.3	30.5	32.3	32.5	30.8	31.6	31.4	31.1	.31.8	32.2	30.5	31.3	32.2
22	Max....	41.5	41.0	39.9	41.3	41.1	40.3	35.6	32.3	31.7	36.6	32.8	32.4	32.1	31.6	32.3
	Min....	37.4	37.0	36.4	37.4	37.1	36.7	32.9	32.0	31.6	33.9	32.3	32.3	32.1	31.5	32.2
24	Max....	36.3	37.4	38.0	36.4	37.2	38.0	34.5	34.9	34.4	37.2	37.9	38.5	32.5	31.9	32.4
	Min....	34.0	35.5	36.4	34.1	35.2	36.4	33.4	34.5	34.1	35.3	36.2	37.0	32.3	31.7	32.3
25	Max....	32.9	33.7	34.3	33.1	33.7	34.5	32.6	33.5	33.4	33.7	34.3	35.1	32.3	31.9	32.4
	Min....	32.7	33.5	34.0	32.7	33.5	34.1	32.6	33.4	33.4	33.5	34.0	34.5	32.3	31.8	32.4
26	Max....	32.2	33.0	33.4	32.1	32.3	33.4	32.4	33.4	33.4	32.8	33.4	34.0	32.3	32.0	32.5
	Min....	31.2	32.7	33.2	28.9	32.2	32.8	32.3	33.2	33.0	32.6	33.1	33.5	32.2	31.8	32.3
27	Max....	32.1	32.2	32.8	32.0	32.2	32.2	32.3	33.1	33.0	32.2	33.0	33.4	32.4	32.1	32.5
	Min....	28.6	31.5	32.4	22.1	25.8	30.7	32.1	32.8	32.6	31.1	32.5	33.0	32.1	31.7	32.3
Ave.	Max..	32.76	33.01	33.13	32.86	33.13	33.40	31.82	32.26	32.08	32.49	32.48	32.87	32.20	31.83	32.47
	Min..	31.43	32.41	32.80	31.14	32.23	32.88	31.06	32.02	31.86	31.66	32.16	32.62	31.56	31.65	32.35
	Range	1.33	0.60	0.33	1.72	0.90	0.52	0.76	0.24	0.22	0.83	0.32	0.25	0.64	0.18	0.12

TABLE 66.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, MARCH, 1915.

Date—Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1 Max....	32.1	32.3	32.0	32.1	32.3	32.2	31.6	32.6	32.5	31.9	31.4	32.3	31.8	32.1	32.5
Min....	24.0	25.8	29.4	23.0	26.4	29.5	29.3	32.3	32.1	25.9	30.4	31.9	28.9	31.5	32.3
2 Max....	32.1	32.3	32.2	32.1	32.3	32.4	31.8	32.4	32.3	32.1	31.7	32.2	32.0	31.7	32.4
Min....	30.7	31.8	32.2	31.2	32.2	32.3	31.2	32.3	32.2	30.7	31.5	32.1	31.7	31.6	32.3
3 Max....	32.0	32.4	31.9	32.2	32.4	32.3	31.7	32.4	32.4	31.8	31.1	32.1	31.4	31.1	32.5
Min....	21.6	26.0	29.0	23.4	27.4	31.2	25.1	31.9	31.7	25.4	29.9	31.4	26.1	30.0	32.3
4 Max....	32.0	32.3	32.0	32.0	32.3	32.3	31.5	32.1	32.2	31.5	31.1	31.6	31.4	31.1	32.4
Min....	25.1	27.9	29.7	25.9	28.6	31.4	27.0	31.6	31.7	27.1	29.9	31.2	27.8	30.1	32.2
5 Max....	31.2	31.7	31.8	31.4	32.0	32.4	30.7	31.6	31.8	31.1	31.2	31.7	31.3	31.2	32.3
Min....	29.3	30.4	31.0	30.6	31.9	32.3	28.9	31.5	31.4	30.1	31.0	31.5	30.0	30.9	32.2
6 Max....	31.8	32.1	32.1	31.9	32.2	32.4	31.1	31.8	31.6	31.5	31.6	31.9	31.7	31.5	32.2
Min....	31.5	32.0	32.0	31.6	32.1	32.3	31.0	31.8	31.6	31.4	31.5	31.8	31.6	31.4	32.1
8 Max....	32.3	32.4	32.4	32.1	32.4	32.5	31.6	32.2	32.0	31.9	32.1	32.2	32.0	32.7	32.3
Min....	31.9	32.1	32.2	31.8	32.1	32.2	31.3	31.9	31.6	31.5	31.7	32.0	31.6	31.4	32.1
9 Max....	32.0	32.0	32.4	31.9	32.1	32.5	31.8	32.2	32.0	32.3	32.0	32.3	32.0	31.7	32.3
Min....	31.0	31.7	32.1	29.4	31.3	32.2	31.1	32.0	31.5	31.2	31.5	31.9	31.4	31.3	32.1
10 Max....	32.3	32.4	32.3	32.0	32.4	32.4	32.0	32.3	31.9	32.4	32.0	32.2	32.3	31.7	32.3
Min....	31.8	32.3	32.2	31.6	32.1	32.3	31.7	32.1	31.6	32.3	32.1	32.1	32.1	31.5	32.0
11 Max....	32.2	32.5	32.3	32.5	33.3	33.4	32.0	32.2	31.9	32.5	32.3	32.3	32.3	31.8	32.2
Min....	32.1	32.3	32.3	32.1	32.3	32.4	31.8	32.1	31.7	32.3	32.2	32.1	32.1	31.7	32.1
12 Max....	37.6	38.5	37.6	38.4	39.4	38.8	32.4	32.3	32.0	33.9	32.4	32.3	32.3	31.9	32.3
Min....	29.5	32.3	32.3	29.5	32.2	32.4	30.9	32.0	31.7	32.1	32.2	32.1	32.0	31.5	32.0
13 Max....	43.1	43.2	41.8	42.7	42.9	41.7	39.5	37.3	34.3	38.5	35.2	32.6	32.3	31.9	32.3
Min....	31.9	32.8	33.1	31.0	32.5	33.2	31.8	32.1	31.8	32.3	32.2	32.2	32.0	31.5	32.0
15 Max....	41.9	39.4	38.3	41.4	39.4	38.5	39.7	38.2	37.0	39.6	38.1	37.5	33.4	31.8	32.2
Min....	34.9	35.4	35.7	34.6	35.2	35.8	34.6	35.6	35.4	34.9	35.4	35.8	32.2	31.6	32.1
16 Max....	40.4	38.3	38.8	39.4	39.1	39.5	37.5	38.8	37.1	38.0	38.6	37.8	32.4	31.8	32.3
Min....	31.4	33.2	33.9	32.0	33.1	34.0	32.5	33.8	33.6	33.1	34.0	34.1	32.3	31.6	32.1
17 Max....	36.6	38.0	37.8	38.8	39.7	39.4	36.1	36.5	34.8	36.3	36.1	35.3	32.3	32.0	32.3
Min....	29.0	32.3	33.0	30.0	32.4	33.2	30.6	33.4	33.4	31.9	33.0	33.6	32.1	31.6	32.1
18 Max....	43.1	41.9	41.2	43.1	43.5	42.7	41.3	40.5	37.6	41.2	39.9	38.2	32.3	31.9	32.3
Min....	30.5	32.6	34.0	30.8	32.6	33.6	31.9	33.0	33.0	32.5	32.9	33.4	32.1	31.5	32.1
19 Max....	44.5	42.2	41.5	43.4	43.3	42.6	41.0	41.1	38.7	41.8	40.8	39.2	32.3	31.9	32.3
Min....	32.1	33.4	34.4	32.2	33.4	34.5	32.9	34.5	34.4	33.4	34.3	34.7	32.1	31.6	32.1
20 Max....	47.3	41.6	41.2	45.4	41.9	41.8	43.1	40.0	38.5	41.5	40.5	39.5	32.7	31.9	32.3
Min....	32.3	33.7	34.8	32.4	33.7	34.9	33.2	34.8	35.1	33.6	34.8	35.6	32.3	31.6	32.1
22 Max....	38.1	38.2	37.8	38.2	38.3	38.0	37.4	37.0	35.5	38.0	37.3	36.6	32.3	31.9	32.3
Min....	32.8	33.6	34.1	33.0	33.6	34.3	33.4	33.5	33.4	33.4	34.0	34.4	32.2	31.7	32.2
23 Max....	46.0	44.1	43.2	45.1	44.5	43.9	41.0	40.8	38.4	42.6	41.4	39.6	32.8	31.9	32.3
Min....	32.1	33.2	34.0	32.1	33.0	33.9	32.4	33.9	34.0	33.2	34.0	34.6	32.0	31.5	32.2
24 Max....	44.2	43.7	42.4	44.3	43.8	42.5	42.1	40.6	38.0	42.5	40.8	39.2	34.0	31.9	32.3
Min....	32.5	33.9	34.8	32.7	33.8	34.9	32.6	34.4	34.6	33.8	34.7	35.5	32.2	31.6	32.2
25 Max....	41.4	41.1	41.2	41.4	41.4	41.7	40.2	40.2	39.0	40.4	40.4	39.8	34.4	31.8	32.2
Min....	38.9	39.2	39.1	38.8	39.1	39.5	38.1	38.3	37.6	38.9	38.7	38.6	33.1	31.5	32.2
26 Max....	35.7	37.6	38.0	36.2	37.6	38.3	33.6	34.8	34.9	35.9	36.4	36.2	32.3	32.0	32.3
Min....	30.3	32.9	33.7	30.8	32.8	33.9	30.9	33.9	34.1	32.8	33.7	34.8	32.2	31.8	32.3
27 Max....	39.3	40.2	39.4	39.9	40.4	39.9	36.5	36.1	34.5	37.6	36.9	35.8	32.0	32.0	32.3
Min....	29.7	32.0	32.9	29.4	31.7	33.0	30.5	32.6	33.0	31.8	32.9	33.6	31.5	31.6	32.2
29 Max....	31.5	32.3	32.6	31.0	31.8	32.8	31.4	32.6	33.0	32.2	32.9	33.7	31.8	32.0	32.4
Min....	28.4	30.9	32.4	27.9	30.4	32.5	29.8	32.3	32.5	31.0	32.6	33.4	30.4	31.9	32.3
30 Max....	33.5	33.3	32.3	33.4	33.6	32.5	32.0	31.8	32.3	32.6	32.1	32.8	31.9	32.0	32.4
Min....	27.3	29.9	31.7	25.8	28.3	31.5	27.9	31.5	31.9	28.4	31.8	32.3	31.4	31.6	32.2
31 Max....	34.9	33.2	33.3	34.4	34.3	34.5	31.9	32.2	32.1	32.4	32.4	32.6	32.1	31.9	32.3
Min....	30.4	32.1	32.4	30.0	31.8	32.6	31.2	32.1	32.0	32.0	32.2	32.6	31.4	31.8	32.3
Ave. Max..	37.01	36.64	36.29	36.92	36.99	36.81	35.26	35.28	34.38	35.70	35.14	34.80	32.29	31.82	32.32
Min..	30.48	32.06	32.90	30.50	32.07	33.18	31.24	33.01	32.91	31.74	32.71	33.31	31.36	31.43	32.16
Range	6.53	4.58	3.39	6.42	4.92	3.63	4.04	2.27	1.47	3.96	2.43	1.49	0.93	0.39	0.16

TABLE 67.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, APRIL, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1	Max....	41.2	39.3	38.5	42.2	40.2	39.7	34.4	33.3	32.3	36.3	34.9	34.0	32.2	31.7	32.3
	Min....	32.1	32.6	33.0	32.2	32.6	33.3	31.8	32.1	32.1	32.4	32.3	32.6	32.1	31.6	32.3
2	Max....	43.9	41.4	40.4	43.9	41.9	41.1	40.8	39.4	37.0	40.4	39.1	37.7	32.3	31.8	32.3
	Min....	32.6	33.4	34.0	32.6	33.4	34.3	32.3	33.1	32.9	33.0	33.4	33.6	32.1	31.6	32.3
3	Max....	45.3	45.2	43.4	45.1	45.0	43.7	44.2	42.3	38.7	43.4	41.5	39.4	32.3	31.9	32.4
	Min....	31.9	33.1	34.0	31.9	33.0	34.0	32.3	34.0	33.7	33.2	34.0	34.4	32.1	31.6	32.3
5	Max....	46.0	45.0	43.5	46.6	45.7	44.3	44.9	42.8	40.3	44.5	42.4	41.0	33.5	31.7	32.3
	Min....	38.9	38.8	38.7	38.7	38.7	38.7	38.4	38.5	37.7	38.8	38.6	38.4	32.2	31.6	32.3
6	Max....	57.4	54.2	51.9	57.9	55.9	53.6	54.6	51.3	46.0	53.7	50.5	47.0	39.5	31.8	32.4
	Min....	39.5	38.4	38.3	38.8	38.2	38.1	38.2	38.3	37.9	38.4	38.3	38.6	32.3	31.6	32.3
7	Max....	60.1	58.6	55.8	60.0	59.2	57.0	58.2	54.6	49.3	56.9	53.5	49.9	41.5	31.8	32.4
	Min....	41.7	41.6	42.1	41.0	41.1	41.8	41.4	42.1	41.8	42.0	42.2	42.5	33.4	31.6	32.3
8	Max....	60.8	58.3	55.9	59.4	58.3	56.2	57.5	54.9	50.0	56.3	53.2	50.2	41.4	31.8	32.5
	Min....	41.4	41.0	41.7	39.8	39.6	40.6	40.5	41.8	42.5	40.7	41.5	42.9	32.3	31.6	32.3
9	Max....	55.5	53.8	51.9	55.8	54.5	52.7	54.0	51.4	48.1	53.0	50.2	48.7	44.6	33.4	32.9
	Min....	47.0	46.1	45.9	46.2	45.7	45.7	46.0	45.9	45.3	45.4	45.6	45.6	34.7	32.0	32.7
10	Max....	54.0	52.6	51.0	54.4	53.1	51.5	53.1	50.7	48.7	52.5	50.2	49.6	45.2	39.4	37.5
	Min....	50.7	50.2	49.4	50.9	50.2	49.7	50.2	49.3	47.7	49.9	48.9	48.6	42.4	34.9	33.9
12	Max....	40.3	40.7	41.2	40.1	40.5	41.0	40.5	41.4	40.9	41.1	41.5	41.8	40.5	40.2	41.4
	Min....	36.4	37.5	39.0	35.6	36.8	38.5	36.9	39.4	40.4	38.0	39.6	41.2	37.5	39.5	40.8
13	Max....	57.1	53.3	51.4	57.4	56.1	53.8	53.7	51.5	47.0	52.9	50.2	47.3	53.1	46.7	42.3
	Min....	33.2	34.9	36.5	32.5	34.0	35.7	34.3	36.8	37.9	34.8	36.6	38.1	35.6	37.6	39.1
14	Max....	62.9	58.6	56.4	63.3	59.9	58.1	56.8	54.6	49.8	57.3	54.8	51.6	55.1	49.5	44.7
	Min....	39.2	38.2	39.1	38.1	37.7	38.6	57.0	39.0	40.2	37.8	38.6	40.3	37.6	40.2	41.5
15	Max....	69.7	61.5	57.3	69.1	62.9	58.7	63.5	56.5	51.2	61.7	55.6	52.6	55.4	49.5	45.5
	Min....	37.1	39.5	41.7	36.2	38.1	40.9	37.6	41.3	42.7	37.9	40.3	42.9	39.3	42.3	43.3
16	Max....	54.1	52.0	50.5	55.2	53.3	51.3	52.9	50.2	48.3	52.4	49.7	49.1	51.1	48.0	47.0
	Min....	46.8	47.5	48.0	46.5	47.4	47.9	46.9	47.7	47.0	47.2	47.1	47.7	46.5	46.3	46.4
17	Max....	70.3	64.9	59.9	71.0	66.6	62.2	66.6	59.8	52.4	63.5	58.2	53.4	59.0	50.6	46.0
	Min....	34.7	37.5	39.9	33.6	35.9	38.6	36.4	40.4	42.1	36.4	39.2	41.7	58.7	42.1	43.9
19	Max....	73.8	68.6	64.4	73.3	69.6	66.0	70.4	64.7	57.9	68.2	63.6	59.1	61.8	55.0	50.5
	Min....	49.9	50.3	50.7	49.9	50.2	50.8	49.8	50.5	49.6	49.5	49.7	50.2	49.6	48.0	48.3
20	Max....	74.0	68.1	64.9	72.7	68.6	65.8	70.9	65.6	59.7	68.1	64.0	60.6	62.3	57.0	52.9
	Min....	50.6	51.8	52.9	50.6	51.5	52.8	51.4	53.0	52.8	51.1	52.0	53.0	49.6	50.5	51.0
21	Max....	65.9	62.1	58.7	64.7	62.0	59.0	64.1	59.1	55.8	62.0	57.5	56.1	56.4	53.1	51.5
	Min....	45.9	48.0	50.0	46.1	47.4	49.7	47.3	50.4	51.6	46.9	48.5	50.8	46.0	49.4	50.5
22	Max....	68.0	65.1	61.6	69.0	66.7	63.3	67.2	62.1	56.6	65.2	61.4	57.7	63.3	56.5	52.5
	Min....	50.2	50.7	51.3	50.0	50.3	51.0	50.5	51.5	51.2	49.9	50.4	51.1	48.9	49.6	50.7
23	Max....	83.7	76.6	71.8	84.0	78.2	74.1	81.2	73.0	65.1	77.6	71.0	66.2	73.7	65.5	58.4
	Min....	54.6	54.5	54.7	54.4	54.5	54.8	54.9	55.2	54.1	54.6	54.5	54.6	54.2	54.0	53.9
24	Max....	86.1	80.6	75.7	84.9	81.2	77.2	83.7	76.9	68.7	80.3	75.2	69.8	75.7	68.4	62.0
	Min....	59.5	60.4	60.8	59.9	60.5	61.2	60.8	61.5	60.2	60.0	59.8	60.6	59.8	59.9	59.1
26	Max....	87.8	80.9	77.0	85.7	80.7	77.5	85.8	78.3	71.8	82.2	76.4	72.6	77.6	70.8	65.8
	Min....	61.1	62.5	63.5	61.1	61.8	63.1	62.0	64.1	63.9	61.5	61.7	63.7	60.8	62.5	63.4
27	Max....	84.1	78.2	75.5	81.7	77.7	75.5	82.3	76.8	71.1	79.6	74.8	71.8	74.2	69.7	65.7
	Min....	61.7	63.1	64.3	61.8	62.6	64.0	63.3	65.0	64.8	62.0	62.0	64.4	61.4	63.1	63.8
28	Max....	80.5	78.0	75.0	81.3	77.3	75.1	82.1	76.7	71.0	79.3	74.5	71.6	75.1	70.0	66.0
	Min....	60.5	62.2	63.5	61.0	61.9	63.4	62.3	64.4	64.4	61.1	62.6	64.0	60.5	62.8	64.1
29	Max....	74.5	71.8	68.1	74.6	71.4	68.2	75.1	69.3	66.5	71.8	66.9	66.2	68.4	64.8	64.1
	Min....	56.3	59.4	61.9	57.2	59.1	61.8	58.6	62.5	63.6	57.1	60.1	62.6	57.0	61.7	62.7
30	Max....	55.5	55.7	57.8	55.8	55.7	57.7	56.8	57.1	59.5	54.8	56.0	58.2	55.5	57.5	61.0
	Min....	52.7	54.5	56.0	53.2	54.3	55.8	54.7	58.3	57.0	53.2	54.6	55.9	53.7	56.3	58.5
Ave.	Max..	63.56	60.20	57.69	63.46	60.85	58.63	61.36	57.48	53.22	59.81	56.42	53.97	53.88	48.78	46.70
	Min..	45.63	46.45	47.34	45.38	46.02	47.11	45.99	47.55	47.51	45.88	46.62	47.99	44.63	44.38	45.15
	Range	17.93	13.75	10.35	18.03	14.83	11.52	15.37	9.93	5.71	13.93	9.80	5.93	9.25	4.40	1.55

TABLE 68.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, MAY, 1915.

Date—Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1 Max....	65.3	62.3	60.6	63.3	62.4	60.9	63.7	61.8	58.0	61.8	60.0	58.0	61.6	58.4	56.7
Min....	47.6	49.7	50.8	47.8	48.9	50.7	48.8	51.6	52.8	48.1	49.6	51.8	48.8	52.0	55.0
3 Max....	52.9	54.7	55.9	53.5	54.7	56.3	54.1	56.5	56.9	53.4	53.3	56.0	53.8	55.8	58.0
Min....	52.0	53.3	54.0	51.8	52.9	53.9	53.4	54.6	54.4	53.0	52.9	54.2	53.3	54.3	55.9
4 Max....	49.7	51.0	51.4	49.6	50.6	51.2	51.3	52.0	51.7	51.1	50.6	51.5	52.2	52.0	54.2
Min....	47.0	49.0	49.8	46.4	47.8	49.4	48.6	50.5	50.5	48.6	49.2	50.5	49.4	50.8	53.0
5 Max....	57.8	57.4	55.9	58.6	58.3	57.3	58.1	56.5	53.4	57.8	54.7	54.1	59.0	55.1	53.1
Min....	45.0	46.2	47.5	44.6	45.4	46.5	45.7	47.8	48.5	46.0	46.2	48.6	46.3	48.8	51.5
6 Max....	69.1	64.3	61.2	72.3	67.9	63.6	65.2	60.4	56.4	65.9	61.0	58.3	63.0	59.1	55.1
Min....	45.5	45.9	47.3	44.7	44.9	46.1	45.4	47.3	48.5	45.6	45.8	48.8	44.6	48.0	51.7
7 Max....	57.0	57.9	57.6	58.8	59.1	58.8	58.0	57.5	55.2	57.7	57.2	56.4	59.2	57.2	55.7
Min....	53.4	53.7	54.0	53.6	53.7	54.1	53.2	53.9	53.2	53.9	53.8	54.2	53.9	54.4	55.0
8 Max....	55.5	56.0	55.4	56.9	57.2	56.7	55.7	54.9	52.8	56.0	54.0	54.0	56.9	54.4	53.9
Min....	47.5	48.5	49.6	47.3	47.8	48.9	47.8	49.6	50.1	48.0	49.1	50.4	48.4	50.7	53.2
10 Max....	73.2	66.9	63.4	76.2	69.4	66.5	65.7	61.8	56.1	65.6	61.6	58.0	65.5	59.0	53.4
Min....	39.6	41.0	43.2	38.4	39.4	41.8	39.6	43.1	45.4	40.7	42.5	45.4	40.5	45.1	49.5
11 Max....	78.7	72.6	68.5	79.6	74.2	70.8	73.4	67.7	61.1	71.2	66.7	62.4	68.9	62.2	56.1
Min....	46.4	47.5	49.4	45.7	46.5	48.4	45.8	48.6	49.7	46.7	48.2	50.2	45.4	49.2	52.5
12 Max....	82.9	75.2	71.6	83.1	77.3	73.6	78.3	71.3	65.0	76.0	69.9	66.1	71.9	65.1	59.3
Min....	51.5	52.8	54.3	50.9	51.7	53.5	51.6	53.9	54.7	51.4	52.8	54.5	50.1	53.5	55.7
13 Max....	76.4	69.6	67.6	75.3	70.1	68.5	71.4	68.0	63.6	70.6	66.2	64.1	68.4	63.8	59.8
Min....	55.0	56.5	58.0	54.8	55.6	57.6	54.7	58.0	58.4	55.3	56.5	58.3	54.4	57.0	57.7
14 Max....	81.9	74.4	71.2	80.3	74.8	72.0	76.5	71.5	65.8	75.2	68.9	66.0	70.1	65.3	60.5
Min....	51.0	53.0	54.5	50.2	51.2	53.4	50.2	54.5	56.0	51.0	52.6	55.4	50.0	54.3	57.4
15 Max....	69.0	66.4	64.3	67.4	66.0	64.3	65.8	64.2	60.8	65.0	62.5	60.8	63.0	59.5	58.5
Min....	51.0	53.7	56.2	50.4	52.3	55.2	50.7	56.1	57.9	50.7	53.5	56.7	50.1	55.1	56.8
17 Max....	53.2	53.0	53.0	54.0	53.5	53.6	52.2	53.5	52.1	53.0	52.8	52.6	54.0	52.9	52.8
Min....	44.0	45.7	47.6	43.5	44.7	46.6	44.2	48.2	49.8	45.5	47.2	49.6	45.4	49.0	51.9
18 Max....	53.0	51.9	51.1	53.3	52.0	51.5	51.8	51.7	49.7	52.4	51.1	50.5	53.0	50.5	49.8
Min....	39.3	41.8	44.3	38.0	40.3	43.0	39.7	44.6	46.7	41.0	43.6	46.5	41.1	45.8	50.2
19 Max....	67.5	64.2	61.0	70.3	66.4	63.6	62.7	59.2	54.2	62.2	58.0	55.6	62.5	56.0	51.4
Min....	39.5	40.5	42.2	37.6	38.3	40.7	38.2	42.2	44.3	40.7	41.2	44.3	39.7	44.5	48.2
20 Max....	51.0	50.6	50.5	51.0	50.8	50.4	49.2	49.9	49.4	50.3	49.2	50.0	50.2	49.7	51.1
Min....	46.2	48.0	49.2	46.0	47.2	48.9	45.6	49.5	48.9	46.7	46.5	49.4	46.8	48.9	50.3
21 Max....	67.5	64.1	61.8	70.4	66.6	64.6	64.3	60.5	56.2	64.7	60.5	58.2	64.3	58.9	54.1
Min....	50.5	50.5	50.2	50.6	50.4	50.3	49.2	50.0	49.0	50.5	49.3	49.9	50.5	49.6	50.3
22 Max....	60.9	60.1	68.6	62.0	61.5	60.0	59.4	57.5	54.5	58.5	55.7	55.6	59.0	55.8	54.0
Min....	50.0	50.6	51.8	49.8	50.0	51.3	49.7	51.2	51.6	50.3	49.5	52.3	50.4	52.2	53.3
24 Max....	71.2	69.6	66.7	73.5	71.0	68.5	69.9	66.0	61.6	68.1	64.7	62.5	67.6	70.8	58.7
Min....	55.5	56.2	56.9	55.2	55.7	56.7	55.5	56.5	55.9	55.6	55.4	56.1	55.4	55.8	56.4
25 Max....	68.9	66.8	64.1	70.0	68.2	65.5	67.5	63.8	60.5	66.1	62.7	61.2	65.5	61.4	59.3
Min....	56.5	56.5	57.1	55.9	55.7	56.5	55.9	56.8	56.7	55.9	55.8	57.0	56.2	56.9	58.0
26 Max....	61.4	59.6	59.4	62.7	61.0	60.8	59.4	58.7	57.3	59.0	57.7	56.0	59.6	58.3	58.8
Min....	53.3	55.7	57.0	53.1	54.9	56.9	55.0	56.9	55.5	55.2	56.3	56.1	56.5	56.4	57.4
27 Max....	68.2	63.2	61.5	68.1	64.1	62.3	63.3	60.3	56.3	62.3	59.1	57.3	61.4	57.2	54.6
Min....	41.0	42.6	45.2	39.4	40.7	43.2	40.9	45.4	48.0	41.7	44.1	47.0	45.0	48.5	52.5
28 Max....	61.2	59.1	57.7	58.7	59.5	58.9	58.9	56.8	54.4	58.1	55.5	55.2	57.5	55.1	54.1
Min....	48.3	49.1	50.4	47.3	47.6	48.9	47.8	49.9	50.8	48.0	48.8	50.7	48.3	50.8	53.1
29 Max....	58.1	57.2	56.5	58.8	57.8	57.0	57.4	56.3	54.3	57.3	55.5	55.1	58.0	55.6	54.8
Min....	51.5	52.1	52.8	51.0	51.4	52.3	51.4	52.5	52.4	51.7	51.9	52.8	51.9	52.6	54.0
31 Max....	83.1	75.4	71.6	83.2	77.4	73.8	74.9	70.9	64.5	74.8	68.9	65.1	71.2	64.7	59.0
Min....	50.8	51.3	52.7	50.1	50.1	51.6	50.0	52.1	53.3	50.4	51.1	53.2	49.7	52.9	55.7
Ave. Max..	65.18	62.45	61.09	65.80	63.54	61.96	62.63	60.36	57.00	62.09	59.15	57.79	61.44	58.22	55.65
Min..	48.42	49.67	51.00	47.86	48.66	50.25	48.41	50.98	51.65	48.94	49.75	51.69	48.93	51.43	53.71
Range	16.76	12.78	10.09	17.94	14.88	11.71	14.22	9.38	5.35	13.15	9.40	6.10	12.51	6.78	1.94

TABLE 69.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JUNE, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1	Max....	81.5	75.9	72.0	81.7	77.4	73.6	78.0	71.6	66.1	75.4	69.4	66.5	71.6	65.5	61.0
	Min....	54.1	55.3	56.9	53.5	54.0	56.0	53.2	56.5	57.3	53.8	54.8	57.0	53.2	56.1	58.1
2	Max....	63.4	63.3	63.0	63.4	63.4	63.2	63.2	63.0	61.3	62.6	61.5	61.4	63.0	60.9	60.8
	Min....	59.9	61.0	61.8	59.8	60.5	61.5	60.0	61.5	60.8	59.2	59.5	60.9	59.1	60.0	60.3
3	Max....	60.8	60.8	60.3	60.8	60.8	60.5	59.6	60.3	58.5	61.1	59.6	59.3	61.5	59.6	59.2
	Min....	57.4	57.8	58.2	57.1	57.4	57.9	57.4	58.4	57.9	57.8	57.4	58.2	58.1	58.3	58.9
4	Max....	83.7	78.3	74.1	84.5	80.0	76.7	79.0	73.6	67.0	77.0	71.8	68.1	75.5	68.5	63.0
	Min....	56.5	56.7	57.0	56.4	56.2	56.8	55.2	57.2	56.9	56.8	55.7	57.5	57.2	57.5	58.6
5	Max....	86.8	80.6	77.0	86.5	81.8	78.9	82.1	76.8	70.0	80.3	75.5	71.1	75.9	70.0	64.6
	Min....	56.0	57.0	58.8	55.2	55.7	57.8	56.1	58.7	59.8	56.2	57.0	59.6	55.9	59.2	61.8
7	Max....	82.1	79.8	75.8	83.1	80.6	77.1	81.3	76.6	70.8	80.3	75.6	71.7	78.2	71.3	68.7
	Min....	62.1	67.8	68.0	64.6	66.9	68.1	67.2	67.4	67.4	67.1	67.4	67.6	67.2	66.7	66.8
8	Max....	70.3	69.8	67.9	74.4	71.7	70.1	70.1	68.3	65.1	70.2	68.1	66.3	72.2	67.8	64.8
	Min....	52.4	53.5	55.9	51.0	51.7	53.9	52.6	56.8	59.2	53.6	55.1	59.0	53.0	58.3	62.9
9	Max....	......	64.1	63.4	67.4	65.1	63.9	64.8	63.7	61.8	64.3	61.7	62.2	64.9	63.1	63.1
	Min....	......	55.7	57.8	53.7	54.5	56.9	54.9	58.4	59.8	55.8	57.8	60.0	56.7	60.5	61.8
10	Max....	......	62.0	60.0	64.7	62.6	60.7	62.5	60.4	58.9	62.0	59.1	59.3	61.9	59.7	59.6
	Min....	......	51.3	53.3	48.5	49.2	51.2	49.8	53.3	55.3	50.6	52.4	55.1	49.8	54.5	58.5
11	Max....	.....	73.8	70.1	78.0	76.3	73.4	75.3	70.6	64.7	73.9	69.8	66.0	75.5	68.0	62.6
	Min....	......	57.5	57.2	58.1	57.5	57.3	57.2	57.5	56.7	58.0	57.0	57.3	57.8	57.4	58.8
12	Max....	......	78.5	74.5	85.6	80.6	77.0	80.6	74.9	68.7	79.0	73.4	69.5	77.6	70.2	65.0
	Min....	......	55.1	56.8	53.5	53.8	55.6	54.0	57.0	58.2	54.9	56.1	58.3	54.5	58.2	61.4
14	Max ...	74.4	70.4	68.7	75.4	71.5	69.7	70.7	68.2	65.2	70.4	67.5	66.1	70.5	67.0	64.6
	Min....	55.1	56.3	58.3	54.5	54.9	57.1	55.2	58.5	60.1	56.5	58.1	60.8	55.5	60.0	63.2
15	Max....	72.8	70.5	68.7	74.6	73.0	70.8	70.8	68.7	65.1	71.2	68.1	66.2	72.2	67.4	64.2
	Min....	58.0	59.2	60.4	57.9	58.5	59.7	58.4	60.5	60.6	59.3	58.9	61.2	59.3	61.1	62.5
16	Max....	68.0	68.8	68.0	69.5	70.0	69.7	68.0	67.4	63.9	69.0	67.6	65.6	69.7	66.2	64.5
	Min....	57.5	57.7	59.0	57.5	57.3	58.2	56.5	59.0	59.6	57.9	58.1	60.1	57.5	59.8	62.6
17	Max....	78.5	76.3	73.0	85.4	81.5	78.3	75.9	72.6	67.5	76.5	71.6	69.2	77.2	70.6	65.9
	Min....	56.4	57.5	59.0	56.4	56.9	58.1	56.5	59.1	59.5	57.7	57.8	60.3	57.5	60.0	62.3
18	Max....	73.0	70.7	68.7	75.2	71.9	70.9	69.9	68.0	64.7	70.2	67.7	65.7	70.9	67.1	65.4
	Min....	56.2	57.4	59.0	56.6	57.0	58.9	55.5	58.8	60.0	56.8	57.8	60.7	56.4	60.4	63.0
19	Max....	71.6	68.7	67.4	75.9	71.8	70.5	69.3	67.4	65.0	69.7	66.8	65.7	70.6	67.3	65.5
	Min....	58.7	60.4	62.0	58.9	60.0	61.8	59.1	62.2	62.4	59.9	61.0	62.5	61.3	63.5	64.3
21	Max....	77.5	74.6	70.8	80.4	77.6	74.0	74.5	70.0	66.0	74.6	70.1	67.1	72.0	66.7	65.5
	Min....	57.3	57.9	59.5	56.8	56.9	58.5	56.7	59.5	60.7	57.7	58.9	61.2	56.9	60.9	64.2
22	Max....	78.0	74.9	72.8	81.3	77.8	75.4	75.3	72.6	68.0	74.9	71.7	69.2	72.5	68.5	65.8
	Min....	58.4	59.1	60.5	58.3	58.3	59.8	58.0	60.6	61.2	59.2	60.0	61.8	58.7	61.5	63.8
23	Max....	83.1	79.0	75.5	84.6	80.7	77.8	80.5	75.8	69.5	78.7	74.5	69.9	73.2	71.2	65.4
	Min....	51.5	53.9	57.3	50.8	52.3	55.6	52.3	57.3	59.6	53.1	55.8	59.4	51.4	57.8	62.1
24	Max....	74.1	71.9	69.1	75.3	73.0	70.3	72.4	69.0	65.0	71.7	66.8	65.6	71.9	65.8	63.7
	Min....	55.5	57.5	60.0	54.6	56.2	58.7	56.4	60.3	61.8	56.5	58.8	61.5	54.7	59.9	62.9
25	Max....	84.8	80.5	76.8	84.6	81.7	78.4	81.5	76.9	69.9	80.3	75.4	70.8	81.1	72.6	66.0
	Min....	57.9	59.1	60.6	57.7	58.4	59.9	57.9	60.6	61.1	58.5	59.5	61.0	57.6	60.0	62.4
26	Max....	92.4	86.1	81.5	90.1	86.2	82.6	86.9	81.4	74.1	85.3	80.2	75.0	85.0	76.6	69.2
	Min....	57.0	59.1	61.5	56.5	57.9	60.6	57.1	61.5	62.8	57.8	60.0	62.5	56.6	61.5	64.6
28	Max....	92.9	87.0	83.5	88.9	85.8	83.1	88.0	83.4	77.0	86.6	82.0	78.0	84.0	77.9	71.9
	Min....	62.6	63.5	65.5	61.7	62.6	64.8	62.3	65.6	67.0	62.0	63.8	66.4	60.8	65.3	68.5
29	Max....	72.8	71.5	70.3	73.1	71.7	70.5	70.9	70.6	68.9	72.0	69.9	69.4	72.4	69.4	69.7
	Min....	65.1	66.3	68.1	64.5	65.6	67.4	63.8	68.2	68.6	64.7	66.5	68.4	63.9	67.0	68.4
30	Max....	87.5	82.8	80.0	90.2	85.7	83.4	83.3	80.5	74.5	83.1	79.5	75.8	85.8	78.9	72.0
	Min....	61.7	61.9	63.1	60.6	60.8	62.0	60.4	63.7	64.3	62.0	62.9	64.4	61.5	63.8	66.6
Ave.	Max..	c77.73	73.87	71.27	78.25	75.40	73.10	74.40	71.25	66.82	73.86	70.19	67.73	73.95	68.38	65.07
	Min..	c57.61	57.90	59.84	56.73	57.35	59.01	57.07	59.93	60.72	57.82	58.78	60.88	57.42	60.36	62.67
	Range	20.12	15.97	11.43	21.52	18.05	14.09	17.33	11.33	6.10	16.04	11.41	6.85	16.53	8.02	2.40

cAverage of 22 days instead of 26 as the rest of the averages.

TABLE 70.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, JULY, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1	**Max**....	**94.3**	**86.8**	**79.9**	**95.8**	**90.0**	**83.0**	**88.3**	**79.8**	**75.8**	**88.4**	**79.5**	**76.7**	**89.2**	**77.6**	**75.9**
	Min....	64.3	64.6	66.0	63.5	63.7	65.3	62.2	66.7	67.0	64.7	65.5	67.2	64.8	67.8	70.1
2	**Max**....	**83.0**	**79.6**	**75.9**	**87.8**	**83.5**	**79.9**	**80.8**	**76.0**	**73.0**	**81.5**	**76.5**	**74.8**	**81.7**	**75.8**	**72.9**
	Min....	64.1	65.2	66.6	63.5	64.4	66.0	64.6	67.1	67.5	65.1	65.6	67.7	64.7	67.2	70.0
3	**Max**....	**83.7**	**81.6**	**78.8**	**84.9**	**83.4**	**80.9**	**80.6**	**78.0**	**72.9**	**80.6**	**77.0**	**74.5**	**78.9**	**74.5**	**71.6**
	Min....	61.4	62.0	63.8	60.8	61.5	63.4	59 0	64.2	65.6	62.2	63.3	66.1	62.3	66.7	69.8
5	**Max**....	**68.5**	**67.8**	**66.8**	**71.0**	**70.5**	**69.3**	**66.0**	**67.0**	**64.7**	**69.4**	**67.6**	**66.5**	**66.6**	**65.6**	**65.3**
	Min....	55.9	57.2	59.2	55.4	56.4	58.1	54.5	59.5	60.8	57.2	58.2	61.0	57.2	60.8	64.5
6	**Max**....	**81.3**	**77.0**	**74.3**	**83.8**	**79.4**	**76.9**	**74.1**	**73.5**	**68.5**	**78.0**	**73.1**	**70.8**	**74.0**	**69.0**	**65.4**
	Min....	54.7	55.0	56.8	54.0	54.0	55.7	52.4	57.0	58.6	55.2	56.4	59.1	53.0	57.8	62.4
7	**Max**....	**66.2**	**66.4**	**66.5**	**66.2**	**66.3**	**66.7**	**63.0**	**66.2**	**64.8**	**66.5**	**65.3**	**66.0**	**66.1**	**65.2**	**65.2**
	Min....	64.7	64.1	64.7	63.1	63.6	64.4	60.5	64.3	63.8	63.9	63.1	65.0	62.4	63.6	65.1
8	**Max**....	**77.2**	**74.6**	**72.1**	**81.6**	**80.0**	**77.2**	**74.5**	**73.4**	**68.3**	**75.0**	**71.0**	**69.1**	**73.6**	**69.2**	**65.8**
	Min....	59.7	60.4	61.5	59.1	59.7	61.0	56.4	61.2	61.3	60.6	60.2	62.3	60.1	61.5	63.0
9	**Max**....	**92.1**	**84.5**	**80.9**	**94.5**	**88.1**	**84.1**	**83.8**	**80.0**	**73.7**	**82.9**	**76.6**	**73.9**	**81.4**	**74.8**	**68.7**
	Min....	57.4	58.0	59.8	57.0	57.1	59.3	54.6	60.4	61.6	57.9	58.5	61.8	55.4	60.0	63 8
10	**Max**....	**93.2**	**86.3**	**82.5**	**93.4**	**88.1**	**84.4**	**87.6**	**81.6**	**75.9**	**84.8**	**79.7**	**76.0**	**84.5**	**77.3**	**71.4**
	Min....	64.1	64.9	66.4	63.8	64.3	66.0	62.3	66.2	66.5	63.5	64.8	66.3	63.0	65.6	67.5
12	**Max**....	**92.3**	**87.8**	**84.4**	**91.5**	**88.4**	**85.8**	**88.3**	**84.1**	**78.5**	**85.4**	......	**78.5**	**87.2**	**80.2**	**75.5**
	Min....	69.1	69.4	70.1	68.8	68.9	69.7	68.2	70.0	69.8	68.4	......	69.6	68.7	69.9	71.3
13	**Max**....	**96.5**	**90.6**	**86.8**	**94.2**	**90.5**	**87.6**	**91.6**	**86.6**	**80.4**	**88.3**	......	**80.4**	**90.7**	**82.6**	**77.2**
	Min....	67.9	68.5	70.0	67.1	67.7	69.5	67.2	69.9	70.6	66.7	......	70.0	66.8	70.3	72.8
14	**Max**....	**90.1**	**85.6**	**81.6**	**88.9**	**85.5**	**82.2**	**85.3**	**81.6**	**77.9**	**84.4**	......	**77.6**	**86.3**	**80.1**	**76.9**
	Min....	71.3	71.7	72.8	70.6	70.9	72.3	69.4	72.8	72.9	70.0	......	72.2	70.6	73.1	74.9
15	**Max**....	**77.5**	**77.1**	**76.2**	**77.7**	**77.6**	**77.0**	**75.6**	**76.8**	**73.9**	**77.6**	......	**74.7**	**79.3**	**76.4**	**74.8**
	Min....	70.8	71.2	72.2	70.3	70.6	71.7	69.4	72.5	72.3	71.0	......	72.3	71.8	73.5	73.3
16	**Max**....	**85.6**	**83.[illegible]**	**80.9**	**88.5**	**86.7**	**84.2**	**83.3**	**82.0**	**77.1**	**85.6**	**82.3**	**78.9**	**86.5**	**80.5**	**76.6**
	Min....	70.2	69.6	70.0	69.7	69.2	69.5	67.5	70.5	70.2	70.1	69.9	70.6	70.2	71.2	73.0
17	**Max**....	**93.9**	**89.5**	**85.9**	**95.1**	**91.2**	**88.4**	**88.6**	**86.0**	**80.1**	**88.8**	**85.0**	**81.2**	**89.8**	**82.7**	**77.6**
	Min....	68.3	68.7	70.1	67.6	68.1	69.6	66.6	70.6	71.2	69.0	70.3	71.8	69.5	72.6	74.8
19	**Max**....	**78.6**	**76.9**	**75.9**	**79.6**	**78.3**	**77.5**	**76.5**	**76.4**	**73.6**	**80.2**	**78.1**	**75.8**	**79.2**	**76.4**	**74.4**
	Min....	65.4	67.0	69.1	64.7	66.0	68.0	65.1	69.6	70.5	66.8	68.8	70.6	67.3	71.0	72.1
20	**Max**....	**78.3**	**77.3**	**75.4**	**80.3**	**79.3**	**77.5**	**77.3**	**76.1**	**71.9**	**79.6**	**77.2**	**74.2**	**76.3**	**73.5**	**71.5**
	Min....	63.2	64.4	66.1	62.4	63.5	65.4	62.2	66.7	67.6	64.9	66.8	68.7	64.4	68.1	69 8
21	**Max**....	**75.6**	**76.4**	**74.0**	**76.3**	**76.9**	**75.7**	**75.3**	**74.3**	**71.0**	**76.6**	**74.4**	**72.1**	**76.5**	**72.4**	**69.7**
	Min....	59.5	60.8	63.0	58.2	59.2	61.8	58.4	63.5	65.2	61.0	63 2	65.7	58.8	64.1	68.7
22	**Max**....	**84.5**	**82.1**	**78.8**	**86.8**	**84.4**	**81.5**	**82.6**	**79.8**	**73.8**	**83.7**	**80.1**	**75.8**	**82.9**	**76.3**	**68.7**
	Min....	57.4	58.5	61.1	55.8	56.8	59.1	55.8	61.3	63.2	58.3	60.8	63.3	56.5	62.3	66.9
23	**Max**....	**92.6**	**86.2**	**82.9**	**93.5**	**88.0**	**85.3**	**86.2**	**82.5**	**76.5**	**85.5**	**81.3**	**77.6**	**85.7**	**78.5**	**72.9**
	Min....	60.8	62.0	64.1	59.4	60.5	62.8	60.0	64.4	66.0	61.7	63.8	66.3	59.8	65.0	68.8
24	**Max**....	**83.8**	**80.1**	**76.4**	**84.1**	**81.2**	**77.8**	**79.6**	**76.0**	**73.2**	**79.4**	**75.2**	**73.6**	**80.1**	**74.5**	**72.1**
	Min....	65.0	65.9	67.5	64.0	64.9	66.8	63.6	67.3	68.2	64.4	66.1	68.0	63.6	67.4	70.1
26	**Max**....	**82.1**	**80.7**	**78.1**	**83.9**	**83.0**	**80.6**	**80.7**	**78.5**	**73.6**	**81.5**	**78.6**	**75.4**	**82.2**	**76.5**	**72.1**
	Min....	64.5	65.4	66.6	63.9	64.8	66.2	63.8	67.0	67.3	65.8	66 8	68.0	65.8	68.0	68.7
27	**Max**....	**72.4**	**71.2**	**70.0**	**72.7**	**71.6**	**70.5**	**70.6**	**70.1**	**68.6**	**71.5**	**69.9**	**69.4**	**71.8**	**69.9**	**70.0**
	Min....	63.6	64.7	66.2	62.7	63.7	65.6	63.0	66.6	67.2	64.5	66.1	67.7	63.8	67.1	68.8
28	**Max**....	**74.9**	**73.8**	**72.3**	**75.1**	**74.5**	**73.4**	**73.1**	**72.5**	**69.6**	**73.9**	**72.3**	**70.6**	**74.9**	**71.8**	**69.2**
	Min....	66.6	66.4	66.8	66.3	66.2	66.7	65.4	67.0	66.4	66.8	66.9	67.1	67.0	67.4	68.1
29	**Max**....	**78.2**	**76.2**	**73.8**	**78.2**	**76.9**	**74.9**	**76.7**	**74.1**	**70.2**	**77.1**	**74.1**	**71.6**	**78.3**	**73.0**	**68.9**
	Min....	65.6	65.6	66.0	65.1	65.0	65.8	64.3	66.3	66.1	65.9	66.0	66.8	65.8	66.8	67.5
30	**Max**....	**87.1**	**82.1**	**78.7**	**88.5**	**84.2**	**80.8**	**81.7**	**79.0**	**74.9**	**84.4**	**80.4**	**77.4**	**84.5**	**78.8**	**71.2**
	Min....	70.0	69.6	69.8	69.8	69.6	70.0	68.8	69.9	68.9	69.9	69.7	69.8	70.6	70.4	69.2
31	**Max**....	**85.5**	**83.5**	**80.5**	**85.4**	**84.1**	**82.0**	**83.1**	**80.6**	**75.8**	**84.0**	**80.8**	**77.6**	**85.8**	**79.7**	**72.2**
	Min....	69.4	69.8	70.6	69.0	69.6	70.5	68.6	70.8	70.4	70.2	70.9	71.5	70.6	71.8	70.6
Ave.	**Max**..	**83.29**	**80.19**	**77.41**	**84.41**	**81.91**	**79.45**	**79.80**	**77.50**	**73.27**	**80.54**	**76.36**	**74.47**	**80.52**	**75.28**	**71.62**
	Min..	**63.88**	**64.84**	**66.18**	**63.54**	**64.07**	**65.56**	**62.73**	**66.42**	**66.91**	**65.03**	**c64.86**	**67.28**	**64.24**	**67.07**	**69.10**
	Range	**19.41**	**15.35**	**11.23**	**20.87**	**16.84**	**13.89**	**17.07**	**11.08**	**6.36**	**15.51**	**11.50**	**7.19**	**16.28**	**8.21**	**2.52**

cAverage of 23 days only instead of 27 as the rest of the figures.

TABLE 71.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, AUGUST, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2"	4"	6"	2"	4"	6"	2"	4"	6"	2"	4"	6"	2"	4"	6"
2	Max....	77.0	74.6	74.7	76.8	74.1	74.7	74.6	74.8	73.4	75.0	74.5	74.2	76.4	75.7	76.1
	Min....	69.8	70.7	72.1	68.9	69.8	71.6	69.3	72.1	72.3	70.5	72.1	73.3	70.8	73.8	74.6
3	Max...	75.9	75.3	73.9	75.9	75.6	74.8	75.4	74.4	71.2	76.3	74.6	72.8	77.3	74.0	72.5
	Min....	66.9	67.8	68.8	66.3	67.0	68.3	67.0	69.0	68.9	67.9	68.8	69.7	68.8	70.6	71.4
4	Max....	73.3	71.0	69.6	74.1	72.0	70.2	71.3	70.0	68.7	72.4	70.0	69.8	71.7	70.5	70.8
	Min...	64.1	65.1	66.3	63.5	64.4	66.0	64.1	66.6	67.1	65.0	66.3	67.7	65.7	68.4	69.5
5	Max....	63.5	63.6	64.1	63.2	63.4	64.0	62.8	64.3	64.1	63.8	64.2	64.8	63.9	64.9	67.8
	Min....	60.5	61.4	62.8	59.6	60.5	62.1	60.0	63.0	63.9	61.4	62.9	64.6	61.2	64.6	66.5
6	Max....	72.8	69.3	68.5	73.5	70.5	69.4	69.8	68.5	66.0	70.9	68.6	67.3	70.3	67.9	66.4
	Min....	60.1	60.5	61.5	59.6	59.9	60.8	59.5	61.5	61.8	60.6	61.3	62.3	60.3	62.5	64.7
7	Max....	73.5	71.7	70.4	74.4	73.4	72.2	71.1	70.2	67.0	72.0	70.5	68.5	72.8	69.1	66.3
	Min....	58.8	59.6	61.0	58.0	58.7	60.3	58.1	60.9	61.6	59.2	60.6	62.0	58.9	62.0	62.0
9	Max....	87.0	82.8	79.8	89.8	85.3	82.7	80.3	77.8	72.6	83.2	79.9	76.0	84.3	77.5	71.5
	Min....	62.3	63.2	65.0	61.5	62.3	64.2	61.3	64.1	65.0	62.9	64.5	66.2	62.0	65.6	68.1
10	Max....	90.8	85.3	82.1	92.6	87.1	84.6	83.9	80.3	74.9	86.4	81.9	77.9	86.8	78.9	73.5
	Min....	63.1	64.6	66.7	62.0	63.3	65.7	61.8	65.4	66.4	63.7	65.7	67.6	62.5	66.8	68.8
11	Max....	71.1	70.3	70.4	70.9	70.3	70.4	68.9	69.6	68.6	70.0	69.7	69.7	70.0	69.6	71.5
	Min....	66.0	67.2	69.1	65.0	66.1	68.2	64.6	67.8	68.0	66.0	67.9	69.2	65.0	68.8	69.8
12	Max....	69.3	68.1	67.9	69.5	68.3	68.0	67.9	68.0	66.8	68.9	68.0	67.8	68.5	68.0	68.5
	Min....	64.1	64.8	66.0	63.5	64.1	65.3	63.7	65.8	65.9	64.7	65.7	66.7	64.6	66.4	67.4
13	Max....	80.5	76.4	74.0	83.3	79.3	75.8	76.7	73.4	70.3	77.8	73.5	71.7	77.6	72.8	68.6
	Min....	62.9	63.2	64.0	62.4	62.7	63.7	62.3	64.1	64.2	63.4	63.9	64.9	63.0	64.6	66.6
14	Max....	78.0	74.1	71.3	78.9	75.8	72.6	74.9	71.3	69.3	75.6	71.4	70.5	75.4	71.1	69.0
	Min....	62.0	62.7	64.3	61.0	61.6	63.4	61.2	64.1	64.7	62.3	63.7	65.4	61.6	65.0	66.5
16	Max....	83.2	80.6	78.3	85.1	83.1	80.9	79.0	77.0	72.7	80.3	77.6	74.5	81.1	75.8	70.6
	Min....	64.8	65.5	66.8	64.2	64.8	66.3	63.9	66.3	66.7	65.1	66.1	67.4	64.7	67.2	67.8
17	Max....	72.3	71.5	70.9	74.9	74.2	73.6	70.6	71.0	68.6	71.3	70.9	69.9	71.3	70.0	69.9
	Min....	62.8	64.7	66.9	62.0	63.6	66.1	62.9	66.6	66.5	64.1	66.3	67.5	64.2	67.3	68.0
18	Max....	82.1	78.3	75.5	85.1	81.1	78.7	77.0	74.5	69.6	77.0	74.1	70.8	77.7	71.6	67.1
	Min....	52.9	54.8	58.0	51.2	52.8	56.0	52.5	57.8	60.6	53.8	57.1	60.6	51.5	59.4	64.1
19	Max....	86.7	82.1	78.8	89.0	84.6	81.6	81.6	77.9	72.0	81.5	78.0	73.6	82.5	75.0	67.8
	Min....	56.9	58.4	61.2	54.6	56.6	59.8	55.4	60.5	62.5	57.0	59.8	62.6	55.1	61.5	65.5
20	Max....	78.3	74.5	72.8	79.1	75.9	74.0	75.0	71.9	69.0	74.8	71.6	70.2	74.8	70.7	67.8
	Min....	59.3	61.4	63.7	57.8	59.6	62.4	58.5	62.6	64.3	59.5	62.4	64.6	58.0	63.5	65.6
21	Max....	66.2	65.9	65.7	66.1	65.9	65.8	65.4	65.6	64.8	66.3	65.6	65.7	66.0	65.6	66.9
	Min....	63.8	64.2	65.4	63.2	63.8	65.0	63.2	64.8	64.5	64.0	64.6	65.5	64.0	65.1	66.0
23	Max....	84.1	79.6	76.9	87.3	82.6	80.4	78.9	75.9	71.0	78.9	76.0	72.6	80.1	73.9	68.4
	Min....	59.2	60.5	62.1	58.3	59.5	61.5	58.7	62.0	63.0	59.9	61.6	63.5	58.7	62.6	65.6
24	Max....	77.5	74.3	73.0	78.6	75.9	74.3	74.3	72.0	69.8	74.5	71.8	70.9	73.8	71.3	68.2
	Min....	65.5	66.2	67.3	65.2	66.1	67.4	65.4	67.0	66.7	66.0	66.8	67.5	66.1	67.4	67.5
25	Max....	71.8	71.0	69.8	72.6	72.3	71.1	70.1	68.9	66.1	70.0	68.7	67.1	70.8	67.5	66.7
	Min....	60.7	62.2	63.9	59.8	61.3	63.1	60.4	63.2	63.6	61.3	63.0	64.4	60.9	63.6	65.0
26	Max....	77.4	72.9	71.5	79.1	75.4	73.5	74.0	70.8	67.5	74.0	70.6	68.7	74.4	69.8	66.4
	Min....	55.6	58.0	60.6	54.4	56.6	59.5	55.1	59.8	61.3	56.4	59.4	61.8	56.0	60.9	63.8
27	Max....	78.3	74.4	71.8	78.9	75.4	73.5	73.4	70.8	66.6	73.9	70.9	67.9	74.9	69.2	64.8
	Min....	50.8	53.9	57.4	48.7	51.5	55.5	50.4	56.3	59.0	51.4	55.5	59.0	49.8	57.6	61.8
28	Max....	81.1	76.9	74.0	81.5	78.1	75.8	75.9	73.1	68.1	76.3	73.3	69.6	78.0	70.6	65.9
	Min....	53.0	55.3	58.2	51.1	53.2	56.6	51.7	56.9	59.1	53.0	56.2	59.3	51.1	57.8	62.1
30	Max....	71.2	69.5	67.7	71.4	70.2	68.8	68.5	67.1	64.0	68.9	67.1	65.1	70.3	66.0	63.4
	Min....	54.5	56.8	59.1	54.0	56.0	58.4	53.8	58.0	59.8	54.9	57.6	60.0	54.8	59.5	61.5
31	Max....	76.5	71.7	69.4	76.5	72.7	70.9	71.4	68.7	64.7	72.2	68.8	66.1	72.5	66.9	63.1
	Min....	50.5	52.9	55.7	48.8	51.0	53.4	49.7	54.6	57.1	50.6	53.9	57.0	49.6	55.7	60.4
Ave.	Max..	76.90	74.07	72.42	78.01	75.48	73.94	73.57	71.84	68.75	74.32	72.00	70.14	74.74	70.92	68.45
	Min..	60.42	61.76	63.61	59.41	60.65	62.75	59.79	63.12	64.03	60.95	62.84	64.63	60.34	64.17	66.18
	Range	16.48	12.31	8.81	18.60	14.83	11.19	13.78	8.72	4.72	13.37	9.16	5.51	14.40	6.75	2.27

TABLE 72.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, SEPTEMBER, 1915.

Date—Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1 Max....	80.0	75.4	72.5	79.9	76.7	74.3	75.5	71.9	67.0	75.7	72.2	68.7	76.6	69.8	65.0
Min....	53.5	55.7	58.1	52.5	54.4	57.3	52.8	57.1	58.7	53.6	56.6	59.0	52.5	58.0	61.5
2 Max....	83.3	78.9	75.5	82.8	79.8	77.2	78.8	75.0	69.5	78.9	75.3	71.3	80.4	73.0	66.9
Min....	55.6	57.9	60.3	54.8	56.8	59.6	54.9	59.1	60.8	55.8	58.5	61.1	54.7	60.0	63.2
3 Max....	78.7	76.3	74.4	78.2	76.8	75.4	75.5	73.5	69.3	75.5	73.6	70.9	76.4	71.6	67.9
Min....	60.5	62.0	63.6	59.7	61.2	63.2	59.6	62.6	63.4	60.3	62.1	63.8	59.6	63.3	65.2
4 Max....	73.7	72.8	71.4	74.0	73.3	72.2	73.5	71.2	68.0	71.5	70.1	68.5	73.7	69.8	67.3
Min....	63.5	64.1	65.1	63.0	63.7	65.0	63.0	64.3	64.4	63.0	63.9	65.0	62.9	64.8	66.0
6 Max....	65.3	65.0	64.7	65.4	65.2	65.1	65.4	64.9	63.8	65.4	64.9	64.7	65.4	64.7	65.0
Min....	63.0	63.1	63.5	62.6	62.9	63.3	63.1	63.5	63.1	63.3	63.6	63.9	63.2	63.5	64.7
7 Max....	74.5	72.0	70.3	75.2	72.9	71.5	73.4	70.5	66.9	72.6	70.4	68.0	73.9	68.9	66.0
Min....	62.1	62.3	62.7	61.8	62.1	62.7	62.3	62.9	62.3	62.5	62.7	63.2	62.6	63.1	64.1
8 Max....	81.1	76.7	74.7	81.9	78.5	77.0	78.7	74.9	70.8	78.3	74.5	72.0	78.7	73.0	69.5
Min....	64.2	64.7	65.3	63.9	64.3	65.4	64.6	65.4	64.8	64.7	65.3	65.7	65.1	65.9	66.5
9 Max....	73.6	72.2	70.8	76.2	74.8	73.1	73.1	71.1	68.5	72.3	70.7	69.3	73.9	70.4	69.5
Min....	64.7	65.3	66.5	64.0	64.7	66.3	65.1	66.7	66.7	65.2	66.3	67.3	65.6	67.7	68.8
10 Max....	78.2	75.4	71.3	81.0	78.8	74.6	78.0	72.1	67.5	75.5	70.9	67.8	76.0	68.3	67.9
Min....	57.2	59.1	61.4	55.9	57.6	60.2	58.1	61.5	62.7	58.4	61.0	63.1	57.8	62.6	66.0
11 Max....	75.4	73.4	71.1	75.8	74.0	72.4	74.8	71.7	68.1	73.9	71.3	69.2	75.9	70.5	67.4
Min....	63.5	63.7	64.2	63.3	63.5	64.1	63.8	64.3	64.0	63.8	64.1	64.5	63.8	64.5	65.8
13 Max....	83.3	79.6	77.5	88.9	84.2	81.8	81.3	78.4	73.7	80.6	78.1	75.2	80.6	75.7	71.8
Min....	66.0	66.4	67.2	65.5	66.0	66.9	66.3	67.4	66.9	66.4	67.1	67.8	66.8	68.2	69.0
14 Max....	89.1	83.8	81.3	92.1	87.8	84.5	86.8	82.2	77.1	85.3	81.2	78.1	83.0	78.2	74.0
Min....	68.2	68.7	69.3	68.1	68.7	69.8	69.0	69.9	69.3	68.9	69.6	70.0	69.2	70.1	70.9
15 Max....	83.9	79.8	77.2	84.8	81.6	78.5	82.0	77.7	74.8	80.1	76.5	75.4	80.2	76.1	74.0
Min....	70.1	70.9	71.7	69.9	70.6	71.8	70.8	72.0	71.6	70.7	71.5	72.3	70.6	71.8	72.5
16 Max....	83.0	79.2	75.7	85.6	82.1	78.2	80.1	75.7	73.4	81.3	76.4	74.7	80.5	75.4	73.4
Min....	67.5	68.2	69.3	66.9	67.5	68.8	68.1	69.3	69.5	68.0	68.9	69.8	68.0	69.7	71.2
17 Max...	78.0	75.2	74.3	78.9	76.7	76.0	77.1	74.5	71.7	76.1	74.7	73.3	77.8	74.7	72.5
Min....	64.5	65.6	67.3	63.5	64.6	66.3	65.2	67.4	68.2	65.5	67.2	68.9	65.6	68.9	70.6
20 Max....	75.4	72.5	69.9	77.0	74.7	71.7	74.2	70.2	67.9	73.0	69.8	68.5	72.7	68.6	68.5
Min....	59.9	61.5	63.4	59.0	60.7	62.8	61.2	63.7	64.6	61.2	63.1	64.8	60.7	64.9	67.3
21 Max....	61.4	60.3	61.0	62.1	61.5	62.0	60.9	61.2	60.5	60.5	60.9	61.1	61.3	61.5	63.8
Min....	49.7	52.7	56.3	49.0	51.3	54.7	51.4	56.5	59.0	51.6	55.8	59.4	52.3	58.9	61.8
22 Max....	71.5	66.2	65.3	74.3	69.2	67.7	68.5	65.9	62.5	67.5	65.0	62.9	67.6	63.4	60.8
Min....	44.5	47.6	48.0	42.0	45.3	48.7	45.6	50.5	53.6	45.4	50.0	53.7	45.7	52.1	57.6
23 Max....	70.2	65.7	63.5	72.9	68.8	65.3	68.2	63.6	61.3	67.0	63.0	61.7	64.4	60.8	59.6
Min ...	48.2	50.1	52.8	46.4	48.6	51.6	49.0	52.8	54.9	49.1	52.0	54.8	48.5	53.5	57.5
24 Max....	78.9	72.9	71.0	81.0	76.4	73.7	76.2	71.5	67.2	74.3	70.1	67.5	74.7	68.7	64.0
Min....	57.9	58.5	59.4	57.5	58.3	59.4	58.0	59.0	59.0	58.1	58.7	59.5	57.1	58.3	59.8
25 Max....	78.6	73.5	70.7	80.5	76.3	72.8	76.5	71.1	67.8	74.5	70.0	68.0	74.5	68.6	65.1
Min....	59.2	60.0	61.1	58.8	59.5	60.8	59.5	61.0	61.1	59.2	60.1	61.2	58.7	60.5	62.3
27 Max....	58.1	55.5	56.5	58.3	55.7	56.3	56.5	56.6	56.4	56.4	56.0	56.8	55.5	56.5	58.8
Min....	46.3	48.5	51.6	45.5	46.3	49.6	48.5	51.5	54.2	48.3	50.9	54.3	46.3	53.3	56.9
28 Max....	64.2	60.4	59.8	67.4	63.1	62.5	61.3	59.9	57.4	59.8	58.4	57.4	61.0	58.1	56.4
Min....	42.1	45.1	48.0	40.5	42.8	45.3	43.3	47.5	50.6	43.8	47.5	47.5	42.5	48.6	53.8
29 Max....	67.5	62.9	61.5	70.1	65.1	63.9	64.4	62.0	58.3	61.7	59.6	57.7	62.5	58.6	55.5
Min.. .	40.5	43.8	47.1	38.6	41.5	45.4	41.9	47.4	49.8	42.2	46.9	49.5	41.7	48.4	52.4
30 Max....	66.9	61.8	60.8	68.6	64.1	62.6	64.1	61.0	58.0	61.6	58.9	57.4	61.5	58.0	55.3
Min...	43.3	45.7	48.6	41.5	43.8	45.6	45.4	48.5	50.8	43.9	47.5	50.2	42.5	48.6	52.5
Ave. Max..	74.95	71.50	69.71	76.52	73.53	71.62	73.00	69.93	66.70	71.97	69.30	67.45	72.35	68.12	65.84
Min..	57.44	58.85	60.48	56.57	57.88	59.78	58.02	60.48	61.36	58.12	60.01	61.61	57.76	61.17	63.52
Range	17.51	12.65	9.23	19.95	15.65	11.84	14.98	9.45	5.34	13.85	9.29	5.84	14.59	6.95	2.32

TABLE 73.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, OCTOBER, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1	Max....	54.4	54.4	55.0	54.4	54.5	55.0	54.4	54.6	54.0	54.3	54.3	54.4	54.2	54.0	54.8
	Min....	50.6	51.8	53.2	50.0	51.2	52.9	50.8	52.8	53.2	50.6	52.0	53.2	50.4	52.8	54.2
2	Max....	65.6	62.6	61.9	66.7	63.2	63.2	62.6	61.8	58.6	62.4	61.0	59.4	64.7	60.8	57.0
	Min....	50.9	51.8	52.9	50.1	51.1	52.5	51.0	52.5	52.8	51.2	52.2	53.1	51.2	52.5	54.1
4	Max....	64.0	63.0	61.9	64.5	63.8	62.8	63.5	61.6	59.9	63.0	61.5	60.6	63.7	61.2	59.8
	Min....	58.4	58.5	58.8	58.1	58.5	59.0	58.3	58.5	57.8	58.3	58.3	58.3	58.6	58.4	58.6
5	Max....	56.6	56.0	56.4	56.9	56.3	56.7	55.4	55.6	55.0	54.5	54.7	55.2	55.6	55.7	57.5
	Min....	49.3	51.5	53.7	48.5	50.1	52.8	50.3	53.2	53.9	50.5	52.9	54.4	51.1	54.4	56.1
6	Max....	57.1	56.0	56.4	57.4	56.3	56.9	55.5	55.8	54.4	54.5	54.4	54.4	55.8	55.0	54.5
	Min....	48.0	49.3	51.0	46.5	48.0	48.4	48.5	50.6	51.6	48.5	50.3	52.0	48.4	51.2	53.7
7	Max....	52.9	53.0	52.7	53.3	53.4	53.1	52.3	51.9	51.2	51.6	51.1	51.2	51.9	51.0	52.3
	Min....	45.4	47.5	49.2	45.0	46.5	48.5	46.3	48.5	49.5	47.5	48.1	49.5	46.1	48.9	51.8
8	Max....	46.2	46.9	47.4	46.0	46.3	47.0	45.8	46.9	47.1	46.0	47.0	47.6	45.6	47.0	50.1
	Min....	42.4	44.3	46.1	41.4	43.0	45.1	42.9	45.6	45.6	43.3	45.7	46.9	43.0	46.1	49.0
9	Max....	48.4	48.6	48.5	50.2	49.3	48.5	48.4	47.9	48.3	47.5	47.0	47.1	48.6	47.4	47.9
	Min....	39.3	40.8	42.8	38.1	39.5	41.7	39.5	42.3	44.0	39.9	41.9	44.2	39.4	45.1	47.0
11	Max....	64.2	59.4	57.8	66.2	62.3	60.0	61.2	57.4	53.4	59.7	56.4	53.9	58.0	53.1	49.5
	Min....	45.4	45.0	45.7	45.0	44.8	45.1	43.9	44.8	45.2	43.8	44.4	45.0	42.5	44.3	46.9
12	Max....	62.7	60.2	58.8	63.5	61.6	60.7	60.1	58.4	55.0	58.5	57.5	55.3	59.5	55.0	51.8
	Min....	48.0	48.1	49.3	47.3	48.4	48.8	47.0	48.3	49.0	47.0	47.9	49.0	45.5	47.7	49.7
13	Max....	58.6	57.9	56.9	59.0	58.5	57.8	58.0	56.6	54.3	58.0	56.5	55.1	57.7	54.2	52.9
	Min....	52.5	52.0	52.2	52.3	52.0	52.3	51.7	51.6	51.1	51.8	51.2	51.5	50.5	50.3	51.4
14	Max....	59.3	57.5	57.4	59.8	58.4	58.1	58.1	57.3	55.3	58.2	57.1	56.4	57.8	56.1	54.3
	Min....	52.9	52.8	53.1	52.5	52.5	52.9	52.5	52.7	52.4	52.7	52.7	53.0	51.8	51.9	53.0
15	Max....	64.9	60.9	59.8	65.8	62.5	61.1	62.0	59.6	57.0	61.0	58.2	57.4	62.0	58.5	55.4
	Min....	51.0	51.6	52.5	50.6	51.1	52.0	51.0	52.1	52.3	51.3	52.0	52.9	51.0	52.0	53.3
16	Max....	63.7	60.0	58.7	64.9	61.5	60.5	60.7	58.6	55.4	58.8	57.3	55.4	61.5	57.0	53.6
	Min....	45.5	46.2	47.8	43.9	44.6	46.4	45.3	47.5	49.3	45.4	47.1	49.1	44.2	48.5	51.3
18	Max....	61.3	60.2	59.0	61.8	61.4	60.0	60.8	58.7	56.3	60.8	57.2	57.1	61.0	57.3	56.3
	Min....	56.3	56.5	55.6	56.1	56.8	56.3	56.7	55.5	54.0	56.8	55.3	54.7	56.5	54.5	54.4
19	Max....	61.8	60.0	58.0	62.3	61.2	59.0	60.9	58.0	56.2	60.5	57.9	57.0	61.5	57.2	55.8
	Min....	49.8	50.5	51.8	48.5	49.6	50.7	49.7	51.5	52.5	49.9	51.4	52.9	49.7	52.3	54.1
20	Max....	65.6	61.8	60.0	66.7	63.5	61.6	63.0	59.9	57.2	62.2	59.6	58.2	62.5	58.6	55.8
	Min....	49.8	50.0	51.1	48.6	49.0	50.2	49.2	50.8	51.5	49.6	50.6	52.0	48.5	51.0	53.5
21	Max....	63.2	58.7	57.9	64.5	60.8	59.1	59.9	57.7	55.4	59.0	56.8	55.9	57.9	55.5	54.0
	Min....	44.4	45.9	48.5	42.3	43.7	47.5	44.8	47.9	50.3	45.3	48.4	50.5	43.3	49.4	52.3
22	Max....	62.2	57.6	56.8	63.4	59.5	57.0	59.0	56.4	53.9	57.5	55.2	54.0	55.4	53.2	51.8
	Min....	42.1	43.5	44.9	40.3	41.3	43.8	41.7	45.4	47.2	42.0	45.9	47.9	40.6	46.0	49.7
23	Max....	58.8	54.8	54.4	59.5	56.0	55.3	55.8	54.0	52.4	54.4	52.8	52.4	53.5	52.2	51.0
	Min....	42.3	44.7	47.1	40.6	42.7	45.5	42.8	46.5	48.1	43.0	45.8	48.0	41.6	46.5	49.2
25	Max....	62.0	57.4	55.8	63.2	59.6	57.3	59.0	55.4	53.0	57.7	54.4	53.0	56.5	52.6	50.5
	Min....	45.0	45.6	47.0	44.0	44.8	46.2	44.2	46.1	46.8	44.2	45.3	46.6	43.8	45.7	48.4
26	Max....	58.6	55.0	53.0	59.7	56.8	53.7	56.2	52.5	51.1	54.9	51.5	51.2	53.5	50.5	49.8
	Min....	42.5	44.0	45.8	41.1	42.5	44.8	42.2	45.0	47.5	42.3	44.7	46.9	41.8	45.5	48.1
27	Max....	58.7	54.3	53.5	59.4	56.1	54.6	55.4	53.0	51.0	54.0	51.8	51.0	53.7	50.9	49.1
	Min....	43.6	44.5	45.5	42.5	43.4	44.8	43.2	44.9	45.5	43.3	44.4	45.1	41.9	44.3	47.2
28	Max....	61.0	56.2	55.2	61.9	57.8	56.8	57.4	54.9	52.1	56.3	53.9	52.3	55.3	52.1	49.7
	Min....	45.0	45.0	45.9	44.0	44.4	44.9	43.9	45.2	45.0	43.9	45.0	45.6	43.0	44.8	47.4
29	Max....	57.8	53.8	53.7	58.4	55.1	54.5	54.7	53.2	51.3	53.7	52.1	51.4	52.9	51.1	49.7
	Min....	44.8	45.6	46.8	43.8	45.4	46.2	44.5	46.0	47.0	44.6	45.6	46.9	43.6	46.1	47.5
30	Max....	59.6	55.1	54.1	60.8	56.9	55.5	56.7	53.8	51.4	55.3	52.8	51.5	54.4	51.4	49.2
	Min....	40.7	42.3	44.5	39.4	40.7	43.4	40.4	43.8	45.4	40.7	43.1	45.3	40.0	44.6	47.4
Ave.	Max..	59.58	56.98	56.19	60.40	58.18	57.15	57.57	55.82	53.86	56.71	55.00	54.17	56.73	54.18	52.85
	Min...	47.15	48.05	49.34	46.17	47.14	48.57	47.01	48.83	49.57	47.21	48.55	49.79	46.46	49.03	51.13
	Range	12.43	8.93	6.85	14.23	11.04	8.58	10.56	6.99	3.29	9.50	6.45	4.38	10.27	5.15	1.72

TABLE 74.—MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND, NOVEMBER, 1915.

Date—Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″
1	**Max**....	58.6	55.9	55.2	59.1	56.7	56.5	55.5	54.7	52.4	54.7	53.9	52.9	54.6	52.4	50.7
	Min....	45.8	47.5	49.4	45.1	46.5	49.0	45.8	48.5	49.5	46.0	48.1	49.6	45.0	48.9	49.5
2	**Max**....	47.6	47.5	47.9	47.5	47.5	47.9	46.7	47.2	48.1	46.5	46.7	48.1	45.8	48.5	50.0
	Min....	43.8	45.5	47.5	43.0	45.0	47.0	43.8	46.8	47.5	43.8	45.4	47.4	43.8	46.7	48.5
3	**Max**....	50.0	47.1	46.8	50.5	48.0	47.3	47.7	46.4	45.4	46.8	45.3	45.4	44.5	44.4	45.5
	Min....	34.0	36.7	39.5	32.7	35.0	38.2	34.9	39.0	41.5	34.6	38.0	41.0	36.1	41.0	44.2
4	**Max**....	54.5	50.8	50.0	55.2	52.0	51.0	51.5	49.6	47.6	50.6	48.9	47.8	49.8	47.6	46.2
	Min....	42.0	42.4	43.2	41.5	42.1	43.0	41.5	42.6	43.1	41.7	42.4	43.2	41.1	42.3	44.6
5	**Max**....	45.8	45.2	45.5	45.8	45.2	45.5	44.6	44.9	44.7	44.6	44.2	44.9	44.0	44.4	45.5
	Min....	40.4	41.4	42.6	39.4	40.5	42.0	40.1	42.1	43.2	40.5	41.7	43.3	39.2	42.4	44.8
6	**Max**....	48.9	46.8	46.0	49.3	47.2	46.9	46.0	45.4	43.9	45.5	45.1	44.3	44.9	42.8	43.0
	Min....	34.6	36.7	38.7	33.4	35.3	37.5	34.8	37.9	39.8	35.0	37.5	39.6	35.4	39.2	41.9
8	**Max**....	63.0	58.4	54.3	64.3	60.8	57.0	60.3	55.1	52.7	59.7	54.5	53.3	58.6	53.0	49.7
	Min....	51.2	50.0	49.0	51.5	50.6	49.8	49.8	48.5	46.9	50.1	48.5	47.5	49.2	46.6	46.0
9	**Max**....	52.9	49.5	49.1	53.8	51.1	50.2	51.2	49.2	48.2	50.2	48.1	48.0	49.3	47.5	47.1
	Min....	38.6	41.1	43.8	37.5	39.7	42.8	39.1	42.9	44.9	39.4	42.4	44.8	39.4	44.3	45.9
10	**Max**....	43.8	44.2	44.4	43.8	44.3	44.7	43.3	43.9	43.3	43.4	43.6	43.6	42.4	42.1	44.2
	Min....	46.3	38.0	40.1	34.8	36.5	39.0	36.3	39.5	41.4	36.4	38.7	41.0	35.9	40.3	43.1
11	**Max**....	55.9	54.2	52.7	56.0	54.9	53.5	54.5	52.3	49.4	54.6	52.4	50.5	53.8	49.6	47.1
	Min....	48.5	46.9	45.8	48.5	47.0	46.2	46.8	45.5	44.3	47.1	45.3	45.0	45.6	43.8	44.4
12	**Max**....	49.0	47.2	46.0	49.8	48.5	47.1	48.5	46.7	46.4	48.6	46.8	46.6	48.0	46.1	47.4
	Min....	39.3	41.6	44.3	37.8	40.0	43.1	39.7	43.8	45.4	40.1	43.5	45.7	40.0	44.9	45.9
13	**Max**....	45.6	43.5	43.4	43.3	44.5	43.6	45.0	43.6	43.2	44.8	43.3	43.6	43.1	42.5	43.6
	Min....	34.6	36.8	38.8	33.5	35.4	37.7	35.5	38.7	40.5	35.4	38.0	40.5	36.8	40.2	42.5
15	**Max**....	35.4	36.1	37.4	35.4	35.5	36.8	34.9	37.0	38.3	36.0	36.8	38.1	36.1	38.0	40.6
	Min....	34.0	35.8	36.9	33.3	34.8	36.4	34.3	36.5	37.5	34.2	36.4	37.5	35.3	37.3	39.7
16	**Max**....	34.3	35.2	36.1	33.5	34.5	35.7	34.0	35.4	36.4	34.4	35.5	36.4	34.2	36.4	38.8
	Min....	32.9	34.3	35.5	32.2	33.5	34.8	33.0	34.9	36.0	32.7	34.4	35.9	33.7	35.8	38.3
17	**Max**....	42.3	39.3	39.8	42.1	39.7	40.0	39.5	39.4	38.6	42.5	39.8	39.6	36.4	36.5	37.6
	Min....	33.8	34.8	35.7	33.4	34.3	35.4	33.8	35.4	36.0	34.3	35.3	36.3	33.8	35.2	37.5
18	**Max**....	39.9	39.7	39.5	40.1	39.7	39.8	39.2	39.0	38.2	40.1	39.5	39.0	37.7	36.8	37.6
	Min....	33.9	35.0	36.0	33.3	34.3	35.5	33.9	35.6	36.4	34.1	35.4	36.5	34.0	35.3	37.2
19	**Max**....	41.4	41.3	41.1	41.3	41.5	41.4	40.7	40.4	40.0	41.2	40.6	40.8	39.8	39.5	39.8
	Min....	38.0	38.8	39.8	37.7	38.7	39.9	37.9	39.3	39.6	38.6	39.6	40.2	37.9	38.8	39.1
20	**Max**....	38.5	38.7	38.8	38.7	38.8	38.9	38.0	38.1	38.2	38.8	38.5	38.5	37.6	37.6	38.8
	Min....	35.4	36.7	37.7	35.0	36.2	37.5	35.4	37.2	37.8	36.0	37.3	37.9	35.5	37.2	38.5
22	**Max**....	32.9	34.0	34.8	32.6	33.7	34.8	33.3	34.7	35.4	33.5	34.5	35.5	33.7	35.0	37.6
	Min....	32.8	33.9	34.6	32.5	33.6	34.6	33.3	34.6	35.2	33.4	34.3	35.3	33.5	34.8	36.7
23	**Max**....	32.6	33.5	34.2	32.2	33.2	34.0	32.7	34.0	34.6	33.2	33.9	34.7	33.3	34.3	36.2
	Min....	32.3	33.4	34.0	32.1	33.0	34.0	32.5	33.9	34.4	33.0	33.9	34.6	33.2	34.2	36.0
24	**Max**....	35.8	36.5	36.7	35.2	36.0	36.5	34.8	35.5	35.0	35.4	34.2	35.7	33.2	34.0	35.7
	Min....	33.3	34.0	34.5	32.8	33.5	34.4	32.9	34.0	34.3	33.3	35.7	34.7	33.0	33.9	35.5
26	**Max**....	50.8	48.5	47.4	51.9	49.5	48.8	48.4	46.8	44.5	48.8	47.2	45.6	47.5	44.0	41.6
	Min....	43.9	43.7	43.5	43.8	43.8	43.8	43.0	42.7	41.5	43.5	43.0	42.5	42.3	40.5	39.9
27	**Max**....	46.5	45.4	44.9	47.0	45.8	45.0	44.2	44.4	44.0	44.4	44.5	44.9	44.3	43.5	43.2
	Min....	41.5	43.2	44.3	40.8	42.5	44.1	41.6	43.4	43.0	41.7	43.2	43.6	42.0	42.6	42.7
29	**Max**....	34.9	36.4	37.6	34.3	35.5	36.9	35.2	37.1	38.0	35.5	37.1	38.5	36.5	38.1	40.2
	Min....	34.3	35.8	36.9	33.8	34.8	36.1	34.7	36.4	37.1	35.2	36.5	37.5	35.6	37.3	39.3
30	**Max**....	33.9	35.0	36.0	33.5	34.6	35.7	34.0	35.6	36.3	34.7	35.8	36.7	34.9	36.4	38.4
	Min....	33.7	34.7	35.7	33.3	34.3	35.3	33.8	35.3	35.8	34.4	35.4	36.3	34.3	35.9	37.7
Ave.	**Max**..	44.42	43.42	43.25	44.59	42.78	43.65	43.18	42.89	42.34	43.37	42.66	42.75	42.35	41.88	42.48
	Min..	38.20	39.00	40.15	37.16	38.29	39.73	37.78	39.64	40.35	38.03	39.44	40.54	37.91	39.82	41.42
	Range	6.22	4.42	3.10	7.43	4.49	3.92	5.40	3.25	1.99	5.34	3.22	2.21	4.44	2.06	1.06

Considering first tables 39 to 50 inclusive which contain the daily and monthly maximum and minimum and also the average monthly amplitude, of the different types of soil for the second year during which they were not covered with a layer of sand, it will be seen (1) that during the winter months when the soils were frozen the fluctuation, or the difference between the maximum and minimum, was practically negligible in all soils and at all three depths. With the exception of a few cases the monthly amplitude was of equal magnitude not only in all the soils but also in all the various depths, and it amounted as a rule to about 1°F. During a few days towards the middle of February, however, it amounted to several degrees at the upper 6-inch depth, in some of the soils.

(2) Immediately upon thawing in the spring the magnitude of fluctuation began to increase. It became greatest in the sand and gravel and slightly smaller in the loam and clay and least in peat. It continued to increase until June when it reached its maximum in all the soils at all three depths. As an average for this month it ran as follows for the 6, 12, and 18-inch depths respectively: gravel 14.63°, 5.73°, 2.52°; sand 14.67°, 5.51°, 1.37°; loam 11.53°, 1.71°, 0.37°; clay 11.67°, 2.59°, 0.58°; and, peat 4.19°, 0.36°, 0.39°F. At certain individual days during this month it ran as high as 20°F in the case of sand and gravel and only about 5°F in peat, at the 6-inch depth. From June on it began to decrease in every soil and at every depth and continued to diminish until the soils froze again.

(3) The soils which attained the lowest minimum temperature also attained the highest maximum and they arrange in the following descending order: sand or gravel, loam, clay, and peat. The difference, however, between the lowest minimum temperature of the different soils was not very large, the highest average variation for any month was only about 3°F. The difference, however, between the maximum of these soils was quite appreciable and especially betwen the sand or gravel and peat in which it amounted in some months, after complete thawing had taken place, to about 9°F. In other words the magnitude of the minimum temperature attained by the diverse classes of soils was about the same or very close, while that of the maximum varied somewhat and especially between the sand or gravel and peat.

The close equality of the minimum temperature in the diverse classes of soil, therefore, contradicts the common belief that the light soils become greatly colder or reach a far lower temperature during the night than the heavier soils and especially peat, while the rather marked difference in the maximum temperature goes to indicate that it is mainly this which is responsible for the variation in the average temperature observed in the various types of soil during the spring and summer months.

The data on the daily and monthly maximum and minimum and monthly range for the third year are contained in Tables 51 to 62 inclusive. It should be remembered that the soils during this year were covered with a thin layer of sand.

The order and magnitude of the fluctuation of the different soils during the third year agree with those of the second year just discussed, but the order and magnitude of the minimum and maximum disagree most markedly. Indeed, the latter were just reversed in the third year. The magnitude of the maximum became more equal in the various soils while the minimum varied appreciably, but the difference was not as great as was in the maximum in the preceding year, the greatest monthly variation being only about 5° F as against 10° F between the sand and peat.

Evidently, therefore, the cover of sand raised the maximum temperature, as well as it did the average, of the heavy types of soil and especially of peat, to the same degree as that of the light classes of soil. And by so doing it augmented their total intrinsic heat and their minimum temperature did not fall as low as that of the light soils. As already stated it accomplished this rise of temperature mainly by reducing the excess of water-evaporation.

The data of the fourth year during which the soils were not covered with sand and their temperature was measured at 2, 4, and 6-inch depths instead of 6, 12, and 18 as previously, are represented in Tables 63 to 74 inclusive. The results in these tables show that the magnitude and order of amplitude in the 6-inch depth were practically the same as in the second or corresponding year, when the soils remained uncovered, but in the 2 and 4-inch depths, they were of course somewhat different. The degree of fluctuation in these upper depths, and especially in the 2-inch, was higher but surprisingly approximately equal in the various soils. This means that the degree of amplitude in peat at the upper depths, was almost as great as that in sand and gravel.

The order and magnitude of the maximum and minimum at the 6-inch depth in all the soils were also the same as in the second year, but in the 2 and 4-inch depths they differed somewhat. The most important difference, however, is that the magnitude of the minimum of the peat at the 2-inch depth was equal to or slightly lower than that of sand or gravel, while at the lower depths it was always higher.

Temperature records taken at the upper ¼-inch depth by the mercury thermometer with small bulb as already described, also show that the peat at this depth attained in the morning, as a very general rule, a slightly lower minimum than the sand and gravel, at the same depth.

These unexpected large diurnal-nocturnal fluctuations and low minimum temperature of the peat at the surface or upper depths as compared with those of the light mineral soils, are undoubtedly due to the poor heat conductivity of the material. On account of the low heat transferring power of the peat, heat does not travel sufficiently rapidly from the lower depths to replenish some of that which is being lost at the surface and consequently it attains a low minimum, even though the temperature at a slightly lower depth is very high. For the same reason, during the insolation, the surface attains a high temperature. A low minimum and high maximum therefore give a high fluctuation at the surface.

From the above it would seem therefore that the factor of poor heat conductivity of peat predominates and exerts a slightly controlling influence on its temperature at or near its surface.

THE DEGREE OF AMPLITUDE AT DIFFERENT DEPTHS AND THE LAW IT FOLLOWS.

As already seen the magnitude of the diurnal-nocturnal amplitude diminishes with depth. The remarkable fact, however, is that this decrease follows a mathematical law and indeed the geometric law, i. e., the diurnal-nocturnal amplitude of oscillation of temperature decreases in geometric progression as the depth increases in arithmetic progression. The extraordinary closeness with which the actual fluctuation follows this law is shown by Table 75, which contains the observed and calculated fluctuation of the five different types of soil at four different depths. The observed amplitudes were obtained by taking records of the temperature every 20 minutes until the absolute maximum and minimum were attained at all different depths. The calculated values were secured by dividing the lowest observed fluctuation by the one preceding and then multiplying the other observed values by the ratio or constant thus obtained.

TABLE 75.—DEGREE OF DIURNAL AMPLITUDE OF TEMPERATURE AT VARIOUS DEPTHS AND THE GEOMETRIC PROGRESSION LAW IT FOLLOWS.

1915.	Gravel.				Sand.				Loam.				Clay.				Peat.			
	0″	2″	4″	6″	0″	2″	4″	6″	0″	2″	6″	6″	0″	2″	4″	6″	0″	2″	4″	6″
I. July 9-10:																				
Max	102.0	93.5	87.0	81.1	105.0	95.4	90.3	85.0	100.7	86.1	80.4	74.1	97.2	84.6	76.9	74.1	97.9	84.3	74.9	70.1
Min	59.0	63.1	64.9	66.2	57.9	62.6	64.1	66.0	58.9	62.0	66.0	66.0	58.2	63.3	64.8	66.0	55.3	62.6	65.3	66.7
Obs. diff	43.0	30.4	22.1	14.9	47.1	32.8	26.2	19.0	41.8	24.1	14.4	8.1	39.0	21.3	12.1	8.1	42.6	21.7	9.6	3.4
Calc. diff	......	28.98	20.49	14.9	......	34.15	23.78	19.0	......	23.54	13.57	8.1	......	26.11	14.26	8.1	......	15.09	7.69	3.4
II. August:																				
Max	97.6	88.9	83.9	79.8	100.3	91.4	87.1	82.9	94.0	82.6	77.8	73.1	97.9	85.8	80.0	76.3	100.0	86.5	77.8	73.4
Min	58.4	62.7	64.6	66.4	56.0	61.5	63.3	65.6	57.5	61.8	65.3	65.7	58.0	63.5	65.7	67.0	53.9	62.5	65.9	68.1
Obs. diff	39.2	26.2	19.3	13.4	44.3	29.9	23.8	17.3	36.5	20.8	12.5	7.4	39.9	22.3	14.3	9.3	46.1	24.0	11.9	5.3
Calc. diff	......	27.22	18.19	13.4	......	32.2	21.73	17.3	......	21.61	12.31	7.4	......	25.95	14.50	9.3	......	20.53	10.73	5.3
III. August 18-19:																				
Max	91.9	84.0	79.3	75.5	94.0	86.9	82.8	78.8	90.0	78.9	74.5	70.1	87.6	79.0	74.1	71.1	91.9	79.1	71.9	68.2
Min	51.0	55.8	58.4	61.1	48.7	54.0	56.6	59.6	50.0	55.3	60.3	61.6	50.2	56.9	59.7	62.0	45.0	55.1	60.5	63.8
Observ. diff	40.9	28.2	20.9	14.4	45.3	32.9	26.2	19.2	40.0	23.6	14.2	8.5	37.4	22.1	14.4	9.1	46.9	24.0	11.4	4.4
Calc. diff	......	28.21	19.45	14.4	......	33.20	24.11	19.2	......	23.94	14.13	8.5	......	23.64	13.97	9.1	......	18.10	9.26	4.4
IV. August 26-27:																				
Max	86.9	79.4	75.4	71.8	88.5	80.9	77.6	74.1	86.2	75.9	71.3	67.5	84.9	76.1	71.3	68.7	89.2	76.9	69.8	67.2
Min	44.5	50.8	53.8	56.9	41.9	48.7	51.5	55.0	42.7	50.4	55.7	57.8	43.4	51.4	55.1	58.0	37.3	49.7	56.3	60.8
Obs. diff	42.4	28.6	21.6	14.9	46.6	32.2	26.1	19.1	43.5	25.5	15.6	9.7	41.5	24.7	16.2	10.7	51.9	27.2	13.5	6.4
Calc. diff	......	29.24	19.73	14.9	......	34.10	23.56	19.1	......	27.05	15.85	9.7	......	27.41	16.31	10.7	......	24.60	12.89	6.4
V. September 2-3:																				
Max	96.2	85.2	80.2	75.7	101.0	84.7	81.0	77.2	94.7	80.9	75.0	70.1	93.2	81.1	75.5	71.4	97.2	82.4	73.5	68.7
Min	56.7	60.4	62.0	63.4	54.0	59.7	61.1	63.0	55.7	59.6	62.5	62.6	55.7	60.2	62.0	63.3	53.0	59.6	62.6	64.6
Observ. diff	39.5	24.8	18.2	12.3	47.0	25.0	19.9	14.2	39.0	21.3	12.5	7.5	37.5	20.9	13.5	8.1	44.2	22.8	10.9	4.1
Calcul. diff	......	26.70	16.76	12.3	......	33.54	17.84	14.2	......	23.40	12.78	7.5	......	22.50	12.42	8.1	......	16.62	8.57	4.1
VI. October 22-23:																				
Max	70.0	63.0	59.8	57.1	69.6	64.3	61.7	58.9	69.7	60.8	56.8	53.9	66.0	59.0	55.8	54.0	67.8	57.8	53.2	52.5
Min	38.0	42.3	44.6	46.6	36.3	40.5	42.7	45.3	37.2	42.8	46.1	47.4	37.0	43.0	45.3	47.4	33.0	41.5	45.5	49.2
Observ. diff	32.0	20.7	15.2	10.5	33.3	23.8	19.0	13.6	32.5	18.0	10.7	6.5	29.0	16.0	10.5	6.6	34.8	16.3	7.7	3.3
Calc. diff	......	22.10	14.30	10.5	......	23.84	17.04	13.6	......	19.74	10.93	6.5	......	18.23	10.06	6.6	......	14.91	6.99	3.3

It is readily seen from the above table, therefore, that the calculated and observed diurnal amplitudes are remarkably close in all the diverse types of soil and consequently the law is valid.

Since the actual diurnal-nocturnal fluctuations follow the geometric progression law they are expressable then by the formula $A=FR^{n-1}$, where A is the amplitude, F the first fluctuation, R the ratio of any amplitude (except the first) to the preceding one, and n the number of the amplitude. According to this equation, therefore, if the amplitude is known at two different depths it can be calculated at any other depth

THE RELATION BETWEEN THE MINIMUM TEMPERATURE OF THE SOIL AT THE SURFACE AND THAT OF THE AIR ABOVE.

On account of the absorption of the solar energy the temperature of the soil immedately at the surface at the time that it reaches its maximum is many degrees higher than that of the air above, amounting sometimes to about 30°F. In certain sections of the world this difference must be far greater.

During the night, however, i. e., when the minimum temperature is attained at the surface soil, no such great difference exists. Indeed, both the air and surface soil reach practically equal minimum temperature, as the data in Table 76 show. These data were obtained by placing on the surface soil and about four feet in the air, minimum thermometers of the standard type, and taking records every morning for six months. During the months of June, July, August, and September the thermometers were exposed to the sky, but during September, October and November they were covered with wooden boxes with perforations all around them to allow free circulation of air and consequently the rapid attainment of the actual air temperature. For lack of space only the averages for the various months are presented here.

TABLE 76.—MONTHLY AVERAGE MINIMUM TEMPERATURE OF THE SOIL AT THE SURFACE AND THAT OF THE AIR ABOVE.

	June.	July.	August.	September.	October.	November.
Surface soil........................	49.36	58.03	53.88	52.04	39.74	33.48
Air................................	47.90	56.42	52.34	50.88	38.92	31.35

It is to be noted, therefore, that even during the night the surface soil had a higher temperature than the air above, but the difference is comparatively small, amounting to less than 2°F. In many individual nights the air temperature would be that many degrees warmer.

The above results on the soil surface temperature were obtained on a sandy loam. Now it has already been seen that the mineral soils maintain a slightly higher temperature during the night than peat. Hence peat would always have equal or slightly lower temperature at the surface than the air above.

It is an interesting fact that during the night, say at the time that the minimum temperature is attained at the surface soil, the temperature of the air increases with the elevation up to a certain height and the soil temperature increases with the depth, while during the day the reverse is true.

SEASONAL AND YEARLY AVERAGE TEMPERATURE.

From the theoretical as well as from the practical standpoint it is very interesting and important to know what is the seasonal and yearly average temperature. These data of the different types of soil at the various depths for the three years are presented in Tables 77, 78 and 79 inclusive.

TABLE 77.—MONTHLY, SEASONAL AND YEARLY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND.

1912–1913	Gravel.			Sand.			Loam.			Clay.			Peat.			Air.
Season.	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	
Winter:																
Dec....	33.45	34.71	36.81	33.53	35.03	37.32	33.45	35.77	37.69	33.65	35.75	37.12	33.86	35.73	38.36	31.0
Jan....	32.39	33.38	34.82	32.11	33.41	35.06	31.64	33.66	35.18	32.19	33.82	34.94	31.78	33.36	35.78	26.2
Feb....	28.40	29.70	31.67	28.01	29.96	32.09	28.23	30.94	32.53	28.59	30.77	31.99	27.61	30.77	33.31	20.0
Ave....	**31.41**	**32.60**	**34.43**	**31.22**	**32.80**	**34.82**	**31.11**	**33.46**	**35.13**	**31.48**	**33.45**	**34.68**	**31.08**	**33.29**	**35.82**	**25.73**
Spring:																
Mar...	34.16	33.81	33.79	33.88	33.60	33.84	32.10	31.56	32.46	32.95	32.25	32.57	31.33	31.33	32.91	31.0
Apr....	48.84	45.83	44.36	48.40	45.31	44.13	46.38	43.83	42.56	46.21	44.11	43.22	39.76	37.06	39.11	45.9
May...	61.01	57.80	56.35	60.75	57.43	55.65	59.36	56.61	54.36	58.51	56.22	55.03	58.03	55.61	54.20	56.2
Ave....	**48.00**	**45.81**	**44.83**	**47.68**	**45.45**	**44.54**	**45.95**	**44.00**	**43.13**	**45.89**	**44.19**	**43.61**	**43.04**	**41.33**	**42.07**	**44.37**
Summer:																
Jun....	75.72	71.29	69.32	74.30	70.13	67.34	73.80	69.78	65.88	72.74	68.82	66.46	70.54	66.85	64.58	67.6
July...	78.73	75.77	74.74	77.23	74.79	73.34	77.89	75.25	72.55	76.38	74.11	72.79	75.34	73.75	71.96	70.8
Aug....	76.19	73.70	73.23	75.64	73.43	72.53	75.12	73.50	71.87	73.89	72.61	72.02	74.24	73.54	72.45	69.4
Ave....	**76.88**	**73.59**	**72.43**	**75.72**	**72.78**	**71.07**	**75.60**	**72.84**	**70.10**	**74.34**	**71.85**	**70.42**	**73.37**	**71.38**	**69.66**	**69.27**
Autumn:																
Sep....	66.59	65.35	65.45	66.09	65.09	65.34	65.59	65.34	64.96	65.22	64.56	65.12	65.27	65.63	65.69	61.0
Oct....	53.24	53.66	54.46	52.75	53.58	55.07	52.54	54.05	55.07	52.78	52.79	55.11	53.03	54.88	56.37	50.2
Nov...	42.02	42.67	43.71	41.97	42.96	44.42	41.90	43.18	44.33	42.29	42.60	44.42	41.95	43.42	45.45	41.7
Ave....	**53.95**	**53.89**	**54.54**	**53.60**	**53.88**	**54.94**	**53.01**	**54.19**	**54.79**	**53.43**	**53.32**	**54.88**	**53.42**	**54.64**	**55.84**	**50.97**
Yr. ave...	**52.56**	**51.48**	**51.53**	**51.22**	**51.23**	**51.35**	**51.42**	**51.12**	**50.79**	**51.29**	**50.70**	**50.90**	**50.23**	**50.16**	**50.85**	**47.58**

TABLE 78.—MONTHLY, SEASONAL, AND YEARLY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND.

1913-14	Gravel.			Sand.			Loam.			Clay.			Peat.			Air.
Season.	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	
Winter:																
Dec....	36.22	37.91	39.05	35.73	38.13	40.41	36.25	38.81	40.61	36.59	38.62	40.40	37.09	39.74	42.03	31.8
Jan....	33.70	34.81	35.48	33.39	34.85	36.38	33.05	34.80	36.21	34.00	35.14	36.30	33.10	34.76	36.90	27.0
Feb....	33.44	34.53	35.18	32.76	34.36	35.90	33.12	34.73	35.89	33.73	34.89	35.91	33.42	34.74	36.56	12.7
Ave....	**34.45**	**35.75**	**36.57**	**33.96**	**35.78**	**37.56**	**34.14**	**36.11**	**37.57**	**34.77**	**36.22**	**37.54**	**34.54**	**36.41**	**38.50**	**23.83**
Spring:																
Mar...	35.99	36.18	36.33	35.58	35.97	36.55	35.33	35.94	36.25	35.97	36.02	36.56	33.59	34.46	36.03	31.1
Apr....	46.80	45.35	44.73	47.16	45.34	44.34	45.84	44.64	43.23	45.74	44.44	43.74	44.79	43.18	42.82	44.7
May...	59.87	57.47	56.48	60.29	57.31	55.64	59.14	56.93	54.40	59.44	56.73	55.46	59.16	56.41	54.82	58.6
Ave....	**47.55**	**46.33**	**45.85**	**47.68**	**46.21**	**45.51**	**46.77**	**45.84**	**44.63**	**47.05**	**45.76**	**45.25**	**45.85**	**44.68**	**44.56**	**44.80**
Summer:																
Jun....	71.71	69.36	68.35	71.56	68.79	67.12	71.69	69.00	65.97	71.40	68.42	67.18	72.48	69.57	67.24	66.0
July...	75.92	74.08	72.62	75.24	73.30	71.53	75.80	73.27	70.15	75.31	72.25	71.26	76.93	74.06	71.74	71.0
Aug....	73.39	71.99	71.77	72.69	71.69	71.09	73.35	72.20	70.37	72.88	71.20	71.16	74.02	73.15	72.14	68.9
Ave....	**73.67**	**71.81**	**70.93**	**73.16**	**71.26**	**69.91**	**73.61**	**71.49**	**68.83**	**73.20**	**70.62**	**69.87**	**74.44**	**72.26**	**70.37**	**68.63**
Autumn:																
Sept.	63.91	63.58	63.89	63.30	63.42	64.01	63.79	64.05	63.47	63.62	63.55	64.04	64.35	64.84	65.03	60.3
Oct....	55.86	56.16	56.97	55.54	56.15	57.57	55.56	56.71	57.45	55.79	56.45	57.51	56.33	57.87	59.03	54.6
Nov...	39.26	40.97	42.14	38.22	41.50	43.46	39.49	41.87	43.61	39.93	41.72	43.65	39.84	42.92	45.55	37.6
Ave....	**53.01**	**53.57**	**54.33**	**52.35**	**53.69**	**55.01**	**52.95**	**54.21**	**54.84**	**53.11**	**53.91**	**55.07**	**53.51**	**55.21**	**56.54**	**50.83**
Yr. ave...	**52.17**	**51.87**	**51.92**	**51.47**	**51.74**	**52.00**	**51.87**	**51.92**	**51.47**	**52.04**	**51.63**	**51.94**	**52.09**	**52.14**	**52.49**	**47.02**

TABLE 79.—MONTHLY, SEASONAL, AND YEARLY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND.

1914-15	Gravel.			Sand.			Loam.			Clay.			Peat.			Air.
Season.	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	
Winter:																
Dec....	32.28	33.03	33.73	30.23	31.81	32.77	32.54	33.56	33.83	32.29	32.96	33.72	33.30	34.04	35.35	21.6
Jan....	31.81	32.30	32.65	30.59	31.28	31.96	31.28	32.05	32.02	31.87	32.03	32.46	32.05	31.93	32.58	20.4
Feb....	32.21	32.74	32.96	32.19	32.73	33.13	31.49	32.13	31.95	32.11	32.31	32.73	31.93	31.74	32.40	29.4
Ave....	32.10	32.69	33.11	31.00	31.94	32.62	31.77	32.58	32.60	32.09	32.43	32.97	32.43	32.57	33.44	23.80
Spring:																
Mar...	34.33	34.37	34.28	34.34	34.48	34.64	33.27	33.89	33.47	33.86	33.74	33.88	31.86	31.59	32.23	30.1
Apr....	56.16	54.82	52.95	56.22	54.36	53.60	55.25	52.95	50.10	54.41	52.03	50.69	49.90	46.59	45.80	51.6
May...	58.54	57.77	56.76	58.74	58.11	56.78	56.96	56.37	54.34	57.39	55.31	54.92	56.69	54.97	54.48	51.5
Ave....	49.68	48.99	48.00	49.77	48.98	48.34	48.49	47.74	45.97	48.55	47.03	46.50	46.15	44.38	44.17	44.40
ummer:																
Jun....	69.78	67.92	66.79	69.98	68.55	67.22	67.86	66.42	63.79	67.84	65.46	64.45	67.53	64.65	63.65	61.0
July...	75.70	74.18	72.70	76.18	74.96	73.69	73.41	72.82	70.12	74.39	71.55	71.04	74.20	71.51	70.16	67.9
Aug....	70.50	69.45	68.58	70.80	70.00	69.26	68.54	68.06	66.28	69.44	68.17	67.38	69.42	67.50	67.28	63.4
Ave....	71.99	70.52	69.36	72.32	71.17	70.06	69.94	69.10	66.73	70.56	68.39	67.62	70.38	67.89	67.03	64.10
Autumn																
Sept...	67.67	66.74	65.78	68.23	67.41	66.73	67.22	65.90	63.94	66.67	65.47	64.58	66.88	64.74	64.47	63.2
Oct....	53.66	53.65	53.16	54.13	53.97	53.61	53.38	52.78	51.58	52.88	52.34	51.97	52.94	51.46	51.85	51.1
Nov...	41.37	41.67	41.87	41.14	41.52	41.91	40.95	41.45	41.25	41.07	41.18	41.58	40.50	40.73	41.94	39.8
Ave....	54.23	54.02	53.60	54.50	54.30	54.08	53.85	53.38	52.26	53.54	53.00	52.71	53.44	52.31	52.75	51.37
Yr. ave...	52.00	51.56	51.02	51.90	51.60	51.28	51.01	50.70	49.39	51.17	50.21	49.95	50.60	49.29	49.35	45.92

An examination of the foregoing tables shows the following most important facts: (1) In all three years the highest seasonal average temperature occurred in the summer, a slightly lower in the spring and autumn and the lowest in the winter. The fall temperature was slightly higher than that of the spring. (2) In all the four seasons there was a greater or less gradient of temperature at the various depths. During the seasons of spring, summer and fall this gradient diminished with increase in depth but in the winter the reverse was true. (3) The magnitude of the yearly average temperature was practically the same for all types of soil and equal at all three depths, i. e., the upper 18-inch layer of the different types of soil had practically the same magnitude of yearly average temperature. (4) The average air temperature was more or less lower than that of all the soils at any depth in all four seasons.

SEASONAL AND YEARLY MAXIMUM, MINIMUM, AND AMPLITUDE OF TEMPERATURE.

Of equal interest and importance as the average seasonal and yearly average temperature, is the seasonal, yearly maximum, minimum, and amplitude of temperature of the various soils. These data are contained in Tables 80, 81 and 82 for the three years, respectively.

TABLE 80.—MONTHLY, SEASONAL AND YEARLY MAXIMUM, MINIMUM AND AMPLITUDE OF TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND.

1912–1913.		Gravel.			Sand.			Loam.			Clay.			Peat.			Air.
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	
Winter:																	
Dec.	Max.	33.98	35.08	37.08	34.15	35.42	37.58	33.80	36.05	37.89	34.06	36.02	37.34	34.12	35.93	38.54	38.1
	Min.	32.98	34.34	36.55	32.98	34.65	37.07	33.12	35.51	37.48	33.27	35.49	36.90	33.58	35.51	38.18	23.9
	Diff.	1.00	0.74	0.53	1.17	0.77	0.51	0.68	0.54	0.41	0.79	0.53	0.44	0.54	0.42	0.36	14.2
Jan.	Max.	32.58	33.56	35.00	32.30	33.56	35.19	31.80	33.81	35.33	32.34	33.98	35.08	31.93	33.53	35.93	34.2
	Min.	32.20	33.20	34.64	31.94	33.24	34.89	31.47	33.49	35.03	32.01	33.64	34.78	31.62	33.20	35.62	18.2
	Diff.	0.38	0.36	0.36	0.36	0.32	0.30	0.33	0.32	0.30	0.33	0.34	0.30	0.31	0.33	0.31	16.0
Feb.	Feb.	29.35	30.13	31.88	28.97	30.36	32.28	28.75	31.13	32.76	29.03	31.01	32.20	28.48	30.99	33.51	27.9
	Min.	27.77	29.30	31.50	26.59	29.58	31.90	27.84	30.77	32.32	28.14	30.58	31.77	26.98	30.56	33.09	12.1
	Diff.	1.58	0.83	0.38	2.38	0.78	0.38	0.91	0.36	0.44	0.89	0.43	0.43	1.50	0.43	0.42	15.8
Seasonal.	**Max.**	**31.97**	**32.92**	**34.65**	**31.81**	**33.11**	**35.02**	**31.45**	**33.66**	**35.33**	**31.81**	**33.67**	**34.87**	**31.51**	**33.48**	**35.99**	**33.40**
	Min.	**30.98**	**32.28**	**34.23**	**30.50**	**32.49**	**34.62**	**30.81**	**33.26**	**34.94**	**31.14**	**33.24**	**34.48**	**30.73**	**33.09**	**35.63**	**18.07**
	Diff.	**0.99**	**0.64**	**0.42**	**1.31**	**0.62**	**0.40**	**0.64**	**0.40**	**0.39**	**0.67**	**0.43**	**0.39**	**0.78**	**0.39**	**0.36**	**15.33**
Spring:																	
Mar.	Max.	34.98	34.30	34.06	34.81	34.08	34.13	32.61	31.73	32.65	33.48	32.45	32.77	31.54	31.52	33.08	41.6
	Min.	33.29	33.41	33.52	32.91	33.17	33.54	31.66	31.40	32.26	32.49	32.05	32.39	31.14	31.13	32.74	20.5
	Diff.	1.69	0.89	0.54	1.90	0.91	0.59	0.95	0.33	0.39	0.99	0.40	0.38	0.40	0.39	0.34	21.1
Apr.	Max.	53.28	47.52	44.80	53.31	46.92	44.56	50.16	44.28	42.82	49.42	44.55	43.52	40.70	37.35	39.43	56.6
	Min.	43.39	44.77	43.98	42.86	44 27	43.75	42 93	43 44	42.30	43.60	43.73	42.95	38.78	36.80	38.82	35.2
	Diff.	9.89	2.75	0.82	10.45	2.65	0.81	7.23	0.84	0.52	5.82	0.82	0.57	1.92	0.55	0.61	21.4
May.	Max.	66.01	60.02	57.17	66.32	59.77	56.26	63.53	57.22	54.60	62.31	57.00	55.31	59.73	55.85	54.34	67.2
	Min.	54.88	56.35	55.72	53.97	55.83	55.12	55.41	56.10	54.15	54.91	55.66	54.79	56.92	55.38	54.08	45.1
	Diff.	11.13	3.67	1.45	12.35	3.94	1.14	8.12	1.12	0.45	7.40	1.34	0.52	2.81	0.47	0.26	22.1
Seasonal.	**Max.**	**51.42**	**47.28**	**45.34**	**51.48**	**46.92**	**44.98**	**48.77**	**44.41**	**43.36**	**48.40**	**44.67**	**43.87**	**43.99**	**41.57**	**42.28**	**55.13**
	Min.	**43.85**	**44.84**	**44.41**	**43.25**	**44.42**	**44.14**	**43.33**	**43.65**	**42.90**	**43.67**	**43.81**	**43.38**	**42.28**	**41.10**	**41.88**	**33.60**
	Diff.	**7.57**	**2.44**	**0.93**	**8.23**	**2.50**	**0.84**	**5.44**	**0.76**	**0.46**	**4.73**	**0.86**	**0.49**	**1.71**	**0.47**	**0.40**	**21.53**
Summer:																	
June.	Max.	82.17	74.71	70.68	80.80	73.54	67 96	80.15	70.60	66.07	78.59	70.24	66.78	73.24	67.03	64.77	81.5
	Min.	67.54	68.98	68.16	66.13	68.03	66.59	68.62	68.89	65.70	66.92	67.65	66.20	69.05	66.67	64.38	53.7
	Diff.	14.63	5.73	2.52	14.67	5.51	1.37	11.53	1.71	0.37	11.67	2.59	0.58	4.19	0.36	0.39	27.8
July.	Max.	85.15	78.77	75.83	83.65	77.85	73.87	83.12	75.85	72.80	81.55	75.09	73.14	77.85	73.99	72.09	83.0
	Min.	72.08	74.02	73.74	70.10	73.06	72.68	73.29	74.51	72.29	71.69	73.24	72.50	73.98	73.50	71.82	58.5
	Diff.	13.07	4.75	2.09	13.55	4.79	1.19	9.83	1.34	0.51	9.86	1.85	0.64	3.87	0.49	0.27	24.5
Aug.	Max.	82.05	76.41	74.07	82.16	76.46	73.08	80.20	74.18	72.22	79.12	73.41	72.41	76.65	73.87	72.62	81.1
	Min.	69.55	72.13	72.38	67.72	71.67	71.90	70.92	72.83	71.53	69.95	71.81	71.68	72.82	73.22	72.27	57.6
	Diff.	12.50	4.28	1.69	14.44	4.79	1.18	9.28	1.35	0.69	9.17	1.60	0.73	3.83	0.65	0.35	23.5
Seasonal.	**Max.**	**83.12**	**76.63**	**73.52**	**82.20**	**75.95**	**71.64**	**81.16**	**73.54**	**70.36**	**79.75**	**72.91**	**70.78**	**75.91**	**71.63**	**69.83**	**81.87**
	Min.	**69.72**	**71.71**	**71.43**	**67.98**	**70.92**	**70.39**	**70.94**	**72.08**	**69.84**	**69.52**	**70.90**	**70.13**	**71.95**	**71.13**	**69.49**	**56.60**
	Diff.	**13.40**	**4.92**	**2.09**	**14.22**	**5.03**	**1.29**	**10.22**	**1.46**	**0.52**	**10.23**	**2.01**	**0.65**	**3.96**	**0.50**	**0.34**	**25.27**
Autumn:																	
Sept.	Max.	71.11	67.57	66.22	71.02	67.42	65.85	69.55	65.89	65.27	69.15	65.27	65.49	67.30	65.95	65.87	73.3
	Min.	61.41	64.05	64.74	60.40	63.70	64.85	62.25	64.78	64.66	61.72	63.78	64.81	64.04	65.30	65.51	48.7
	Diff.	9.70	3.52	1.48	10.62	3.72	1.00	7.30	1.11	0.61	7.43	1.49	0.68	3.26	0.65	0.36	24.6
Oct.	Max.	55.51	54.96	55.01	55.44	55.09	55.47	54.71	54.56	55.35	54.83	53.52	55.41	54.24	55.16	56.63	59.0
	Min.	50.15	52.82	53.94	49.25	52.63	54.64	50.74	53.58	54.81	50.89	52.03	54.85	52.21	54.60	56.14	41.5
	Diff.	5.36	2.14	1.07	6 19	2.46	0.83	3.97	0.98	0.54	3.94	1.49	0.56	2.03	0.56	0.49	17.5
Nov.	Max.	43.63	43.57	43.80	43.70	43.88	44.82	43.25	43.64	44.62	43.65	43.28	44.77	42.56	43.69	45.68	49.0
	Min.	40.46	42.38	42.87	40.12	42.26	44.10	40.84	42.82	44.04	41.20	42.02	44.13	41.44	43.14	45.28	34.4
	Diff.	3.17	1.19	0.93	3.58	1.62	0.72	2.41	0.82	0.58	2.45	1.26	0.64	1.12	0.55	0.40	14.6
Seasonal.	**Max.**	**56.75**	**55.37**	**55.01**	**56.72**	**55.46**	**55.38**	**55.84**	**54.70**	**55.08**	**55.88**	**54.02**	**55.22**	**54.70**	**54.93**	**56.06**	**60.43**
	Min.	**50.67**	**53.08**	**53.85**	**49.92**	**52.86**	**54.53**	**51.28**	**53.73**	**54.50**	**51.27**	**52.61**	**54.60**	**52.56**	**54.35**	**55.64**	**41.53**
	Diff.	**5.08**	**2.29**	**1.16**	**6.80**	**2.60**	**0.85**	**4.56**	**0.97**	**0.58**	**4.61**	**1.41**	**0.62**	**2.14**	**0.58**	**0.42**	**18.90**
Yearly.	**Max.**	**55.82**	**53.05**	**52.13**	**55.55**	**52.86**	**51.76**	**54.31**	**51.58**	**51.03**	**53.96**	**51.32**	**51.19**	**51.53**	**50.40**	**51.04**	**57.71**
	Min.	**48.81**	**50.48**	**50.98**	**47.91**	**50.17**	**50.92**	**49.09**	**50.68**	**50.55**	**48.90**	**50.14**	**50.65**	**49.38**	**49.92**	**50.66**	**37.45**
	Diff.	**7.01**	**2.57**	**1.15**	**7.64**	**2.69**	**0.84**	**5.22**	**0.90**	**0.48**	**5.06**	**1.18**	**0.54**	**2.15**	**0.48**	**0.38**	**20.26**

TABLE 81.—MONTHLY SEASONAL AND YEARLY MAXIMUM, MINIMUM AND AMPLITUDE OF TEMPERATURE OF DIFFERENT TYPES OF SOIL, COVERED WITH SAND.

1913-1914.		Gravel.			Sand.			Loam.			Clay.			Peat.			Air.
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	
Winter:																	
Dec......	Max....	36.75	38.34	39.32	36.42	38.52	40.70	36.67	39.05	40.83	37.02	38.91	40.64	37.48	39.94	42.26	39.1
	Min....	35.67	37.68	38.83	35.06	37.84	40.18	35.91	38.60	40.41	36.23	38.39	40.20	36.71	39.55	41.86	24.6
	Diff.....	1.08	0.66	0.49	1.36	0.68	0.52	0.76	0.45	0.42	0.79	0.52	0.44	0.77	0.39	0.40	14.5
Jan......	Max....	33.87	34.98	35.63	33.56	35.01	36.49	33.24	34.90	36.27	34.09	35.30	36.39	33.17	34.85	36.97	33.5
	Min....	33.55	34.64	35.35	33.22	34.69	36.28	32.89	34.71	36.14	33.76	34.99	36.21	33.00	34.68	36.83	20.5
	Diff.....	0.32	0.34	0.28	0.34	0.32	0.21	0.35	0.19	0.13	0.33	0.31	0.18	0.17	0.17	0.14	13.0
Feb	Max ...	33.59	34.69	35.36	32.95	34.52	36.07	33.27	34.91	36.06	33.89	35.07	36.10	33.55	34.90	36.74	23.5
	Min ..	33.33	34.41	35.05	32.63	34.25	35.79	32.99	34.61	35.76	33.63	34.78	35.78	33.33	34.63	36.44	1.9
	Diff....	0.26	0.28	0.31	0.32	0.27	0.28	0.28	0.30	0.30	0.26	0.29	0.32	0.22	0.27	0.30	21.6
Seasonal..	**Max....**	**34.74**	**36.00**	**36.77**	**34.31**	**36.02**	**37.75**	**34.39**	**36.29**	**37.72**	**35.00**	**36.43**	**37.71**	**34.73**	**36.56**	**38.66**	**32.03**
	Min....	**34.18**	**35.58**	**36.41**	**33.64**	**35.59**	**37.42**	**33.93**	**35.97**	**37.44**	**34.54**	**36.05**	**37.40**	**34.35**	**36.27**	**38.38**	**15.67**
	Diff.....	**0.56**	**0.42**	**0.36**	**0.67**	**0.43**	**0.33**	**0.46**	**0.32**	**0.28**	**0.46**	**0.38**	**0.31**	**0.38**	**0.29**	**0.28**	**16.36**
Spring:																	
Mar.....	Max....	37.35	36.93	36.71	37.10	36.74	36.77	36.35	36.17	36.43	36.97	36.36	36.74	33.77	34.61	36.19	39.7
	Min....	34.84	35.71	36.07	34.23	35.48	36.35	34.58	35.75	36.10	35.19	35.74	36.41	33.44	34.35	35.90	22.5
	Diff.....	2.51	1.22	0.64	2.87	1.26	0.42	1.77	0.42	0.33	1.78	0.62	0.33	0.33	0.26	0.29	17.2
Apr......	Max....	50.26	47.17	45.52	51.19	47.39	44.81	48.66	45.18	43.43	48.42	45.08	44.00	46.02	43.41	43.02	55.2
	Min....	43.10	44.27	44.10	42.63	44.09	43.88	43.68	44.13	43.04	43.49	43.88	43.48	43.94	42.97	42.67	34.2
	Diff. ...	7.16	2.90	1.42	8.56	3.30	0.93	4.98	1.05	0.39	4.93	1.20	0.52	2.08	0.44	0.35	21.0
May.....	Max....	64.42	59.67	57.31	65.80	59.88	56.14	63.18	57.49	54.64	63.50	57.45	55.75	61.25	56.68	55.05	70.6
	Min....	54.75	56.13	55.74	53.77	55.76	55.09	55.95	56.35	54.18	55.97	56.02	55.23	57.81	56.18	54.62	46.5
	Diff.....	9.67	3.54	1.57	12.03	4.12	1.05	7.23	1.14	0.46	7.53	1.43	0.52	3.44	0.50	0.43	24.1
Seasonal .	**Max....**	**50.68**	**47.92**	**46.51**	**51.36**	**48.00**	**45.91**	**49.40**	**46.28**	**44.83**	**49.63**	**46.30**	**45.50**	**47.01**	**44.90**	**44.75**	**55.17**
	Min....	**44.23**	**45.37**	**45.30**	**43.54**	**45.11**	**45.11**	**44.74**	**45.41**	**44.44**	**44.88**	**45.21**	**45.04**	**45.08**	**44.50**	**44.40**	**34.40**
	Diff.. ..	**6.45**	**2.55**	**1.21**	**7.82**	**2.79**	**0.80**	**4.66**	**0.87**	**0.39**	**4.75**	**1.09**	**0.46**	**1.95**	**0.40**	**0.35**	**20.77**
Summer:																	
June.....	Max....	76.83	71.01	69.19	77.19	71.36	67.73	76.03	69.68	66.28	75.78	69.22	67.57	75.08	69.93	67.44	77.6
	Min....	66.19	67.94	67.58	65.02	67.27	66.55	67.99	68.36	65.67	67.72	67.58	66.87	70.84	69.22	67.06	54.3
	Diff.....	10.64	3.07	1.61	12.17	4.09	1.18	8.04	1.32	0.61	8.06	1.64	0.80	4.24	0.71	0.38	23.3
July.....	Max....	80.74	75.89	73.50	80.58	75.84	72.11	80.03	73.90	70.36	79.42	73.00	71.56	79.67	74.33	71.92	83.0
	Min....	70.88	72.28	71.86	69.33	71.86	70.90	72.47	72.58	69.94	71.90	71.45	71.02	75.39	73.81	71.56	59.0
	Diff.....	9.86	3.61	1.64	11.25	3.98	1.21	7.56	1.32	0.42	7.52	1.55	0.54	4.28	0.52	0.36	24.0
Aug.....	Max....	78.00	74.07	72.41	77.89	73.90	71.57	77.43	72.73	70.59	76.64	71.83	71.53	76.20	73.48	72.30	81.0
	Min....	68.81	70.78	70.99	67.36	70.26	70.57	70.24	71.60	70.08	69.62	70.44	70.84	72.56	72.85	72.00	57.0
	Diff.....	9.19	3.29	1.42	10.53	3.64	1.00	7.24	1.13	0.51	7.02	1.39	0.69	3.64	0.63	0.30	24.0
Seasonal..	**Max....**	**78.52**	**73.66**	**71.70**	**78.55**	**73.70**	**70.47**	**77.85**	**72.10**	**69.08**	**77.28**	**71.35**	**70.22**	**76.98**	**72.58**	**70.55**	**80.53**
	Min....	**68.63**	**70.33**	**70.14**	**67.24**	**69.80**	**69.34**	**70.23**	**70.85**	**68.56**	**69.75**	**69.82**	**69.58**	**72.93**	**71.96**	**70.21**	**56.77**
	Diff.....	**9.89**	**3.33**	**1.56**	**11.31**	**4.90**	**1.13**	**7.62**	**1.25**	**0.52**	**7.53**	**1.53**	**0.64**	**4.05**	**0.62**	**0.34**	**23.76**
Autumn:																	
Sept.....	Max....	68.07	65.43	64.59	68.14	65.61	64.56	67.52	64.61	63.76	67.22	64.19	64.48	66.21	65.14	65.25	72.0
	Min....	59.75	62.40	63.20	57.86	62.02	63.50	61.12	63.46	63.17	60.92	62.87	63.66	62.99	64.55	64.84	48.0
	Diff.....	8.32	3.03	1.39	10.28	3.59	1.06	6.40	1.15	0.59	6.30	1.32	0.82	3.22	0.59	0.41	24.0
Oct......	Max....	58.71	57.76	57.74	58.60	57.80	57.81	58.08	57.22	57.34	58.37	57.06	57.97	57.78	58.17	59.21	65.0
	Min....	52.96	55.18	56.36	52.05	55.05	56.90	53.79	56.21	56.84	53.86	55.90	57.23	55.52	57.42	58.86	44.0
	Diff.....	5.75	2.58	1.38	6.55	2.75	0.91	4.29	1.01	0.50	4.51	1.16	0.74	2.26	0.75	0.35	21.0
Nov.....	Max....	40.56	41.69	42.57	39.50	41.90	43.82	40.57	42.23	43.84	41.08	42.26	44.09	40.44	43.13	45.85	47.0
	Min....	38.00	40.36	41.78	37.06	40.44	43.15	38.68	41.55	43.37	39.10	41.45	43.57	39.36	42.74	45.43	28.0
	Diff....	2.56	1.33	0.79	2.44	1.46	0.67	1.89	0.68	0.47	1.98	0.81	0.52	1.08	0.39	0.42	19.0
Seasonal..	**Max....**	**55.78**	**54.96**	**54.97**	**55.41**	**55.10**	**55.40**	**55.39**	**54.69**	**54.98**	**55.56**	**54.50**	**55.51**	**54.81**	**55.48**	**56.77**	**61.33**
	Min....	**50.24**	**52.65**	**53.78**	**48.99**	**52.50**	**54.52**	**51.20**	**53.41**	**54.46**	**51.29**	**53.41**	**54.82**	**52.62**	**54.90**	**56.38**	**40.00**
	Diff.....	**5.54**	**2.31**	**1.19**	**6.42**	**2.60**	**0.88**	**4.19**	**1.28**	**0.52**	**4.27**	**1.09**	**0.69**	**2.19**	**0.58**	**0.39**	**21.33**
Yearly...	**Max...**	**54.93**	**53.14**	**52.49**	**54.91**	**53.21**	**52.38**	**54.26**	**52.34**	**51.65**	**54.37**	**52.15**	**52.24**	**53.38**	**52.38**	**52.68**	**58.27**
	Min...	**49.34**	**50.98**	**51.41**	**48.35**	**49.75**	**51.60**	**50.03**	**51.41**	**51.23**	**50.12**	**51.12**	**51.71**	**51.24**	**51.91**	**52.34**	**36.71**
	Diff....	**5.59**	**2.16**	**1.08**	**6.56**	**3.46**	**0.78**	**4.23**	**0.93**	**0.42**	**4.25**	**1.03**	**0.53**	**2.14**	**0.47**	**0.34**	**21.56**

TABLE 82.—MONTHLY, SEASONAL, AND YEARLY MAXIMUM, MINIMUM AND AMPLITUDE OF TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOT COVERED WITH SAND.

1914–1915.		Gravel.			Sand.			Loam.			Clay.			Peat.			Air.
		2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	2″	4″	6″	
Winter:																	
Dec......	Max....	33.02	33.57	33.96	31.58	32.31	33 36	32.79	33.74	34.06	32.80	33.21	33.89	33.55	34.18	35.55	28.0
	Min....	31.55	32.78	33.53	29.20	30.99	32.76	31.99	33.38	33.69	31.74	32.75	33.59	33.10	33.92	35.25	15.0
	Diff.....	1.47	0.79	0.43	2.38	1.32	0.60	0.80	0.36	0.37	1.06	0.46	0.30	0.45	0.26	0.30	13.0
Jan......	Max....	31.91	32.38	32.73	30.86	31.47	32.07	31.39	32.13	32.10	31.95	32.15	32.53	32.12	32.03	32.68	28.0
	Min....	31.72	32.20	32.56	30.38	31.13	31.84	31.21	31.97	31.94	31.79	31.94	32.39	31.99	31.84	32.52	12.9
	Diff.....	0.19	0.18	0.17	0.48	0.34	0.23	0.18	0.16	0.16	0.16	0.21	0.14	0.13	0.19	0.16	15.1
Feb......	Max....	32.76	33.01	33.13	32.86	33.13	33.40	31.82	32.26	32.08	32.49	32.48	32.87	32.20	31.83	32.47	36.2
	Min....	31.43	32.41	32.80	31.14	32.23	32.88	31.06	32.02	31.86	31.66	32.16	32.62	31.56	31.65	32.35	22.5
	Diff.....	1.33	0.60	0.33	1.72	0.90	0.52	0.76	0.24	0.22	0.83	0.32	0.25	0.64	0.18	0.12	13.7
Seasonal..	**Max....**	**32.56**	**32.99**	**33.27**	**31.77**	**32.30**	**32.94**	**32.00**	**32.71**	**32.75**	**32.41**	**32.61**	**33.10**	**32.62**	**32.68**	**33.57**	**30.73**
	Min....	**31.57**	**32.46**	**32.94**	**30.24**	**31.45**	**32.49**	**31.42**	**32.46**	**32.50**	**31.73**	**32.26**	**32.87**	**32.22**	**32.49**	**33.37**	**16.80**
	Diff.....	**0.99**	**0.53**	**0.33**	**1.53**	**0.85**	**0.45**	**0.58**	**0.25**	**0.25**	**0.68**	**0.35**	**0.23**	**0.40**	**0.19**	**0.20**	**13.93**
Spring:																	
Mar.....	Max....	37.01	36.64	36.29	36.92	36.99	36.81	35.28	35.28	34.38	35.70	35.14	34.80	32.29	31.82	32.32	39.6
	Min....	30.48	32.06	32.90	30.50	32.07	33.18	31 24	33.01	32.91	31.74	32.71	33.31	31.36	31.43	32.16	20.6
	Diff.....	6.53	4.58	3.39	6.42	4.92	3.63	4.04	2.27	1.47	3.96	2.43	1.49	0.93	0.39	0.16	19.0
Apr......	Max....	63.56	60.20	57.69	63.46	60.85	58.63	61.36	57.48	53.22	59.81	56.42	53.97	53.88	48.78	46.70	63.0
	Min....	45.63	46.45	47.34	45.38	46.02	47.11	45.99	47.55	47.51	45.88	46.62	47.99	44.63	44.38	45.15	40.1
	Diff.....	17.93	13.75	10.35	18.08	14.83	11.52	15.37	9.93	5.71	13.93	9.80	5.98	9.25	4.40	1.55	22.9
May.....	Max....	65.18	62.45	61.09	65.80	63.54	61.96	62.63	60.36	57.00	62.09	59.15	57.79	61.44	58.22	55.65	62.3
	Min....	48.42	49.67	51.00	47.86	48.66	50.25	48.41	50.98	51.65	48.94	49.75	51.69	48.93	51.43	53.71	40.7
	Diff.....	16.76	12.78	10.09	17,94	14.88	11.71	14.22	9.38	5.35	13.15	9.40	6.10	12.51	6.79	1.94	21.6
Seasonal..	**Max....**	**55.28**	**53.10**	**51.69**	**55.39**	**53.79**	**52.47**	**53.09**	**51.04**	**48.20**	**52.53**	**50.24**	**48.85**	**49.20**	**46.27**	**44.90**	**54.97**
	Min....	**41.51**	**42.73**	**43.75**	**41.25**	**42.25**	**43.52**	**41.88**	**43.85**	**44.03**	**42.19**	**43.03**	**44.33**	**41.63**	**42.42**	**43.67**	**33.80**
	Diff.....	**13.77**	**10.37**	**7.94**	**14.14**	**11.54**	**8.95**	**11.21**	**7.19**	**4.17**	**10.34**	**7.21**	**4.52**	**7.57**	**3.85**	**1.23**	**21.17**
Summer:																	
June.....	Max....	77.73	73.87	71.27	78.25	75.40	73.10	74.40	71.26	66.82	73.86	70.19	67.73	73.95	68.33	65.07	72.7
	Min....	57.61	57.90	59.84	56.73	57.35	59.01	57.07	59.93	60.72	57.82	58.78	60.88	57.42	60.36	62.67	49.3
	Diff.....	20.12	15.97	11.43	21.52	18.05	14.09	17.33	11.33	6.10	16.04	11.41	6.85	16.53	8.02	2.40	23.4
July.....	Max....	83.29	80.19	77.41	84.41	81.91	79.45	79.80	77.50	73.27	80.54	76.36	74.47	80.52	75.28	71.62	77.9
	Min....	63.88	64.84	66.18	63.54	64.07	65.56	62.73	66.42	66 91	65.03	64.86	67.28	64.24	67.07	69.10	57.9
	Diff.....	19.41	15.35	11.23	20.87	16.84	13.89	17.07	11.08	6.36	15.51	11.50	7.19	16.28	8.21	2.52	20.0
· Aug.....	Max....	76.90	74.07	72.42	78.01	75.48	73.94	73 57	71.84	68.75	74.32	72 00	70.14	74.74	70.92	68.45	73.3
	Min....	60.42	61.76	63.61	59.41	60.65	62.75	59.79	63.12	64 03	60.95	62.84	64.63	60.34	64.17	66.18	53.6
	Diff.....	16.48	12.31	8.81	18.60	14.83	11.19	13.78	8.72	4.72	13.37	9.16	5.51	14.40	6.75	2.27	19.7
Seasonal..	**Max....**	**79.31**	**76.04**	**73.70**	**80.22**	**77.60**	**75.50**	**75.92**	**73.53**	**69.61**	**76.24**	**72.85**	**70.78**	**76.40**	**71.53**	**68.38**	**74.63**
	Min....	**60.64**	**61.50**	**63.21**	**59.89**	**60.69**	**62.44**	**59.86**	**63.16**	**63.89**	**61.27**	**62.16**	**64.26**	**60.67**	**63.53**	**65.98**	**53.60**
	Diff.....	**18.67**	**14.54**	**10.49**	**20.33**	**16.91**	**13.06**	**16.06**	**10.37**	**5.72**	**14.97**	**10.69**	**6.52**	**15.73**	**8.00**	**2.40**	**21.03**
Autumn:																	
Sept.....	Max....	74.95	71.50	69.71	76.52	73.53	71.62	73.00	69.93	66.70	71.97	69.30	67.45	72.35	68.12	65.84	73.8
	Min....	57.44	58.85	60.48	56.57	57.88	59.78	58.02	60.48	61.36	58.12	60.01	61.61	57 76	61.17	63.52	52.6
	Diff.....	17.51	12.65	9.23	19.95	15.65	11.84	14.98	9.45	5.34	13.85	9.29	5.84	14.59	6 95	2.32	21.2
Oct......	Max....	59.58	56.98	56.19	60.40	58.18	57.15	57.57	55.82	53.86	56.71	55.00	54.17	56.73	54 18	52.85	61.2
	Min....	47.15	48.05	49.34	46.17	47.14	48.57	47.01	48.83	49.57	47.21	48.55	49.79	46.46	49.03	51.13	41.0
	Diff.....	12.43	8.93	6.85	14.23	11.04	8.58	10.56	6.99	3.29	9.50	6.45	4.38	10.27	5.15	1.72	20.2
Nov.....	Max....	44.42	43.42	43.25	44.59	42.78	43.65	43 18	42.89	42.34	43.37	42.66	42.75	42.35	41.88	42.48	47.4
	Min....	38.20	39.00	40.15	37.16	38.29	39.73	37 78	39.64	40 35	38.03	39.44	40.54	37.91	39.82	41.42	32.1
	Diff.....	6.22	4.42	3.10	7.43	4.49	3.92	5.40	3.25	1.99	5.34	3.22	2.21	4.44	2.06	1.06	15.3
Seasonal..	**Max....**	**59.65**	**57.30**	**56.38**	**60.50**	**58.16**	**57.47**	**57.92**	**56.21**	**54.30**	**57.35**	**55.65**	**54.79**	**57.14**	**54.73**	**53.72**	**60.80**
	Min....	**47.60**	**48.63**	**49.99**	**46.63**	**47.77**	**49.36**	**47.60**	**49.65**	**50.43**	**47.79**	**49.33**	**50.61**	**47.38**	**50.01**	**52.02**	**41.90**
	Diff.....	**12.05**	**8.67**	**6.39**	**13.87**	**10.39**	**8.11**	**10.32**	**6.56**	**3.87**	**9.56**	**6.32**	**4.18**	**9.76**	**4.72**	**1.70**	**18.90**
Yearly ..	**Max....**	**56.70**	**54.86**	**53.76**	**56.97**	**55.46**	**54.60**	**54.73**	**53.37**	**51.22**	**54.63**	**52.86**	**51.88**	**53.84**	**51.30**	**50.14**	**55.23**
	Min....	**45.33**	**46.33**	**47.47**	**44.50**	**45.54**	**46.95**	**45.19**	**47.28**	**47.71**	**45.75**	**46.70**	**48.02**	**45.48**	**47.11**	**48.76**	**36.53**
	Diff.....	**11.37**	**8.53**	**6.29**	**12.47**	**9.92**	**7.65**	**9.54**	**6.09**	**3.51**	**8.88**	**6.16**	**3.86**	**8.36**	**4.19**	**1.38**	**18.75**

The principal facts revealed by the preceding tables may be summarized as follows: (1) The highest seasonal amplitude occurred in the summer, the smallest in the winter and an intermediate between these two in the spring and autumn. The magnitude of the spring and fall fluctuation was about equal and only about half as great as that of the summer; while, the yearly average amplitude was equal in magnitude to that of the spring or fall. (2) The amplitude of the air was far greater than that of any soil at any depth.

ADDITIONAL EXPERIMENTAL DATA ON THE TEMPERATURE OF SAND WITH DIFFERENT AMOUNTS OF ORGANIC MATTER, AT VARIOUS DEPTHS FOR 1913, 1914, AND 1915.

PLAN OF THE EXPERIMENT.

Organic matter possesses two physical properties which exert a very marked influence upon soil temperature. These are color and water-holding capacity. The soils with the largest amount of organic matter will have the darkest color. Since dark color possesses the highest absorbing capacity for heat these soils will tend to be much warmer, during the insolation, than the light colored soils, which reflect a large amount of the solar rays. On the other hand, the soils with the greatest organic matter content will carry also the highest amount of water and water possessing such great specific heat, latent heat of evaporation, and other properties, will tend to keep the temperature of these soils low.

It was in order to ascertain to what extent these two physical properties of the organic matter would oppose each other and which one would predominate, that the following experiment was undertaken. It consisted of measuring the temperature of a soil to which was added different amounts of organic matter (peat). It was prepared by making a long trench over 3 feet deep and 3 feet wide, placing in it, about a foot apart, wooden boxes 3x3x3 feet without bottom and top and filling them with a sandy soil. The soils of the upper 24 inches were then taken out from all the boxes, except one, each soil was thoroughly mixed with the proper amount of peat, and then placed back into its respective box. There were six boxes, one containing soil to which was added no peat, another contained only peat, and the other four had soil with various proportions of peat. The percentage of total organic matter of the various soils, except peat, as determined by the ignition method is shown by the following figures: 1.81, 2.01, 3.32, 5.47, and 6.95%. To the soil showing 1.81% organic matter no peat was added. This amount of organic matter, therefore, was originally present in the soil. This untreated soil was covered with a thin layer of white quartz sand so as to give it a distinct white color. The color of the various soils, therefore, ranged from very white to very black.

The temperature was measured in all the soils at two different depths every day except Sunday for almost four years. It was recorded by means of the electric thermometers already described. During the years of 1912, 1913, and 1914 it was measured at the depths of 5 and 18 inches, but during 1915, at 3 and 6 inches. All the records were made three times a day, morning, noon and evening. The time, however, was so chosen and varied during the different seasons as to obtain very close the actual maximum and minimum temperature.

The data for the first year (1912) has been published in the previous report. In the present paper the results of the other three years will be presented.

On account of limited space the daily average, maximum and minimum temperature have been eliminated and only the monthly, seasonal and yearly will be presented here. These data are submitted in the following pages.

MONTHLY, SEASONAL AND YEARLY AVERAGE TEMPERATURE FOR 1913, 1914 AND 1915.

TABLE 83.—MONTHLY, SEASONAL, AND YEARLY AVERAGE TEMPERATURE OF SOIL WITH DIFFERENT AMOUNTS OF ORGANIC MATTER.

1912–1913	1.81% Org. Mat.		2.01% Org. Mat.		3.32% Org. Mat.		5.47% Org. Mat.		6.95% Org. Mat.		Peat.		Air.
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	
Winter:													
December..	31.81	35.42	32.87	36.50	32.99	37.00	33.25	37.00	33.43	37.17	34.18	38.13	31.0
January....	30.68	33.58	31.54	34.46	31.75	34.95	32.00	34.95	31.99	35.02	32.18	35.71	26.2
February...	26.19	30.50	26.88	31.52	27.10	31.93	27.53	31.73	27.48	31.99	28.66	33.23	20.0
Ave......	**29.56**	**33.17**	**30.43**	**34.16**	**30.61**	**34.63**	**30.93**	**34.56**	**30.97**	**34.73**	**31.67**	**35.69**	**25.73**
Spring:													
March.....	33.94	33.70	34.66	34.16	34.73	34.47	34.55	33.93	34.32	33.27	32.91	32.12	31.0
April.......	48.50	45.04	50.34	45.63	49.83	45.73	49.76	45.90	49.51	45.29	42.24	40.09	45.9
May.......	60.19	56.54	62.08	57.21	62.09	57.47	61.98	57.08	61.85	56.75	59.38	55.33	56.2
Ave......	**47.54**	**45.09**	**49.03**	**45.67**	**48.88**	**45.89**	**48.76**	**45.64**	**48.56**	**45.10**	**44.84**	**42.51**	**44.37**
Summer:													
June.......	72.65	67.75	74.85	69.37	75.43	69.26	75.82	68.67	75.77	68.17	71.21	65.03	67.6
July.......	77.61	73.86	78.44	75.16	79.09	74.67	79.17	74.01	79.10	73.55	75.90	71.69	70.8
Aug.......	75.74	72.81	76.86	74.25	77.56	73.69	77.06	73.16	76.96	72.77	74.39	71.75	69.4
Ave......	**75.33**	**74.81**	**76.72**	**72.93**	**77.36**	**72.54**	**77.35**	**71.95**	**77.28**	**71.50**	**73.83**	**69.49**	**69.27**
Autumn:													
September..	65.99	64.94	66.96	66.62	67.12	65.96	67.07	65.78	67.15	65.52	65.82	65.12	61.0
October....	53.28	54.39	53.86	56.21	53.92	55.32	53.86	55.40	53.84	56.20	54.01	55.90	50.2
November..	42.57	43.71	43.45	45.91	43.53	45.03	42.82	45.18	43.44	45.20	43.14	45.11	41.7
Ave......	**53.95**	**55.68**	**54.76**	**56.25**	**54.86**	**55.44**	**54.58**	**55.45**	**54.81**	**55.64**	**54.32**	**55.38**	**50.97**
Yearly ave..	**51.60**	**52.19**	**52.84**	**52.25**	**52.93**	**52.13**	**52.91**	**51.90**	**52.91**	**51.74**	**51.17**	**50.77**	**47.58**

TABLE 83—1913-1914.—*Continued.*

1913-1914	1.81% Org. Mat.		2.01% Org. Mat.		3.32% Org. Mat.		5.47% Org. Mat.		6.95% Org. Mat.		Peat.		Air.
	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	
Winter:													
December..	36.14	39.25	37.13	41.42	37.14	40.53	36.89	40.72	37.45	41.56	38.70	41.74	31.8
January....	33.13	35.33	34.13	36.33	34.18	36.46	34.26	36.64	34.21	36.61	34.06	36.42	27.0
February...	32.24	34.94	33.36	35.84	33.63	36.10	34.03	36.38	34.34	36.50	34.48	36.30	12.7
Ave......	**33.84**	**36.51**	**34.87**	**37.86**	**34.98**	**37.70**	**35.06**	**37.91**	**35.33**	**38.22**	**35.75**	**38.15**	**23.83**
Spring:													
Mar.......	35.41	36.06	36.53	36.72	36.47	37.02	36.70	37.24	36.66	37.15	34.72	35.85	31.1
April.......	47.26	44.83	47.78	45.01	47.60	45.20	47.31	44.82	47.00	44.48	45.17	42.73	44.7
May.......	61.83	57.06	62.62	57.15	62.61	57.43	62.54	56.91	62.20	56.52	59.11	54.54	58.6
Ave......	**48.17**	**45.98**	**48.98**	**46.29**	**48.89**	**46.55**	**48.85**	**46.32**	**48.62**	**46.05**	**46.33**	**44.37**	**44.80**
Summer:													
June.......	71.19	67.38	74.07	68.34	74.29	68.90	74.66	68.53	74.67	68.22	71.71	66.47	66.0
July.......	76.35	72.15	78.03	72.48	77.66	72.97	78.57	72.66	78.71	72.42	75.87	70.70	71.0
August.....	72.52	70.96	74.98	71.62	74.37	71.89	74.40	71.57	74.47	71.52	73.13	70.78	68.9
Ave......	**73.35**	**70.16**	**75.69**	**70.81**	**75.44**	**71.25**	**75.88**	**70.92**	**75.95**	**70.72**	**73.57**	**69.32**	**68.63**
Autumn:													
Sept.......	63.56	63.42	65.26	64.12	64.88	64.37	65.08	64.36	65.14	64.48	64.36	63.96	60.3
October....	55.56	56.50	56.70	57.26	56.68	57.44	56.85	57.75	56.90	57.92	56.65	57.90	54.6
November..	38.98	42.06	40.42	43.26	40.32	43.45	40.50	43.86	40.55	44.39	41.13	44.72	37.6
Ave......	**52.70**	**53.99**	**54.13**	**54.88**	**53.96**	**55.09**	**54.14**	**55.32**	**54.20**	**55.60**	**54.05**	**55.53**	**50.83**
Yearly Ave..	**52.02**	**51.66**	**53.42**	**52.46**	**53.32**	**52.65**	**53.48**	**52.62**	**53.53**	**52.65**	**52.43**	**51.84**	**47.02**

TABLE 83—1914-1915.—*Concluded.*

1914-1915	1.81% Org. Mat.		2.01% Org. Mat.		3.32% Org. Mat.		5.47% Org. Mat.		6.95% Org. Mat.		Peat.		Air.
	3″	6″	3″	6″	3″	6″	3″	6″	3″	6″	3″	6″	
Winter:													
December..	31.35	33.35	32.53	34.00	33.07	34.51	33.47	34.49	34.13	35.05	34.87	35.57	21.6
January....	30.28	31.48	31.53	32.52	32.13	33.24	32.63	33.27	32.86	33.46	32.76	32.78	20.4
February....	31.75	32.70	32.95	33.51	33.12	33.85	33.28	33.64	33.29	33.66	32.63	32.35	29.4
Ave......	**31.13**	**32.51**	**32.34**	**33.34**	**32.77**	**33.87**	**33.13**	**33.80**	**33.43**	**34.06**	**33.42**	**33.57**	**23.80**
Spring:													
Mar.......	34.10	34.71	35.18	35.23	34.88	35.38	34.90	35.13	35.00	35.39	32.57	32.11	30.1
April.......	55.09	52.97	56.72	53.60	56.10	53.85	55.64	53.12	54.95	52.64	49.40	45.83	51.6
May.......	56.60	55.94	59.65	57.50	59.02	57.58	58.84	57.02	58.56	57.96	56.39	53.62	51.5
Ave......	**48.60**	**47.87**	**50.52**	**48.78**	**50.00**	**48.94**	**49.79**	**48.42**	**49.50**	**48.66**	**46.12**	**43.89**	**44.40**
Summer:													
June.......	67.82	66.07	70.00	67.21	69.51	67.39	69.17	66.76	69.16	65.86	66.28	62.25	61.0
July.......	72.83	71.73	75.88	73.30	75.43	73.45	75.44	73.05	75.11	72.33	72.90	68.76	67.9
August.....	69.43	68.70	71.80	69.71	71.28	70.07	71.35	69.50	70.94	68.91	69.20	66.51	63.4
Ave......	**70.03**	**68.83**	**72.56**	**70.07**	**72.07**	**70.30**	**71.99**	**69.77**	**71.74**	**69.03**	**69.46**	**65.84**	**64.10**
Autumn:													
September..	66.80	65.89	68.78	66.83	68.36	67.07	68.46	66.64	68.03	66.06	66.20	63.40	63.2
October....	52.98	52.99	54.64	53.63	54.50	54.09	55.05	53.80	54.60	53.47	52.81	51.33	51.1
November..	40.80	42.02	42.41	42.60	42.22	42.93	42.70	42.89	42.71	42.91	42.04	42.24	39.8
Ave......	**53.53**	**53.63**	**55.28**	**54.35**	**55.03**	**54.69**	**55.40**	**54.44**	**55.11**	**54.15**	**53.68**	**52.32**	**51.37**
Yearly ave..	**50.82**	**50.71**	**52.68**	**51.66**	**52.47**	**51.95**	**52.58**	**51.35**	**52.45**	**51.48**	**50.67**	**48.91**	**45.92**

Table 83 contains the monthly, seasonal and yearly average temperature for the second year, December 1912 to November 1913. The data show that the temperature of all the soils at the 5-inch depth either completely or almost reached the freezing point in December. During January it remained at or slightly below the freezing point. In February, however, it fell several degrees below this point and was lowest in the soil to which was added no peat, slightly higher in the treated soils and highest in peat. As a matter of fact throughout the winter months peat remained the warmest followed by the soils with an increasing organic matter content. The difference, however, was comparatively very small. The temperature at the 18-inch depth of all the soils reached the freezing point in February.

In March all the soils at both depths had thawed except peat at the 18-inch depth. By April, however, peat also had completely thawed but its temperature was about 7°F lower than that of the other soils at the 5-inch depth and about 5°F at the 18-inch depth. By May the temperature of the peat approached that of the other soils quite close so that the difference was only about 1 or 2°F at both depths. From this month on the various soils divided themselves into two distinct groups as regards their temperature. The sand or untreated soil and the peat maintained a low but almost equal temperature and the soils possessing organic matter in percentages of 2.08, 3.32, 5.47, and 6.95 had a slightly higher temperature but also of practically equal magnitude. Thus, in the month of July, when the highest average temperature was attained, the various soils had the following degree of temperature at the 5 and 18-inch depths, respectively: 1.81% organic matter 77.61°, 73.86°; 2.08% 78.47°, 75.16°; 3.32% 79.09°, 74.67°; 5.47% 79.17°, 74.01°; 6.95% 79.10°, 73.55°; and, peat 75.90°, 71.69°F. In this month the difference in temperature between the sand and peat was greater than at any other month during the summer and fall. The above division or order continued, with small variation, until October, and then the magnitude became more or less equal in all the soils. From October until December, the end of the year, all the soils had approximately the same average temperature.

The data for the third year or cycle are contained also in Table 83. The results of this year reveal exactly the same principles as those of the second year just discussed and consequently need no detailed consideration.

The results of the fourth year are represented at the bottom of Table 83. These records differ from those of the previous years in that they were obtained at 3 and 6-inch depths instead of 5 and 18. Even then, however, the order and behavior of the average temperature at these upper depths agree with those of the lower depths of the preceding years and consequently reveal practically the same principles.

It should be noted that the average air temperature was lower than that of all the soils at both depths every month in the year throughout the three years.

In the spring all the soils with the exception of peat, thawed at about the same time; peat, however, thawed much later.

This investigation goes to prove then that soils either with white color and low moisture content or with black color and high water content have a lower average temperature during the spring and summer than soils possessing these properties in medium proportion. In other words the white color of a soil reflects so much of the sun's rays that it prevents the soils from attaining a high temperature in spite of its low water content and small amount of evaporation, while the excess of water content of a black soil, such as peat, consumes so much of the heat energy in its evaporation process that it keeps the temperature of the soil low in spite of its black color and hence its great heat absorbing power.

MONTHLY, SEASONAL, AND YEARLY MAXIMUM, MINIMUM, AND AMPLITUDE OF TEMPERATURE.

Next, the monthly, seasonal and yearly maximum, minimum and amplitude of temperature of the foregoing various soils for the three years will be considered. These data are shown in Tables 84, 85 and 86, inclusive.

TABLE 84.—MONTHLY, SEASONAL, AND YEARLY MAXIMUM, MINIMUM AND AMPLITUDE OF TEMPERATURE OF SOIL WITH VARIOUS AMOUNTS OF ORGANIC MATTERS.

1912–1913.		1.81% Org. Mat.		2.01% Org. Mat.		3.32% Org. Mat.		5.47% Org. Mat.		6.95% Org. Mat.		Peat.		Air
		5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	
Winter:														
December	Max	33.00	35.79	33.75	36.81	33.79	37.28	34.03	37.29	34.06	37.44	34.50	38.34	38.1
	Min	30.57	35.05	31.67	36.18	31.88	36.71	32.48	36.70	32.82	36.88	33.80	37.91	23.9
	Diff	2.43	0.74	2.08	0.63	1.91	0.57	1.55	0.59	1.24	0.56	0.70	0.43	14.2
January	Max	31.07	33.78	31.87	34.63	32.01	35.10	32.28	35.11	32.27	35.17	32.36	35.85	34.2
	Min	30.15	33.40	31.11	34.27	31.35	34.78	31.64	34.79	31.65	34.86	32.00	35.55	18.2
	Diff	0.92	0.38	0.76	0.36	0.66	0.32	0.64	0.32	0.62	0.31	0.36	0.30	16.0
February	Max	27.78	30.85	28.65	31.78	29.00	32.16	29.21	31.96	29.21	32.26	29.60	33.41	27.9
	Min	24.14	30.04	24.54	31.21	24.57	31.69	25.33	31.46	25.17	31.75	27.56	33.05	12.1
	Diff	3.64	0.81	4.11	0.57	4.43	0.47	3.88	0.50	4.04	0.51	2.04	0.36	15.8
Seasonal	**Max**	**30.62**	**33.47**	**31.42**	**34.41**	**31.60**	**34.85**	**31.84**	**34.79**	**31.85**	**34.96**	**32.15**	**35.87**	**33.40**
	Min	**28.29**	**32.83**	**29.11**	**33.89**	**29.27**	**34.39**	**29.82**	**34.32**	**29.88**	**34.50**	**31.12**	**35.50**	**18.07**
	Diff	**2.33**	**0.64**	**2.31**	**0.52**	**2.33**	**0.46**	**2.02**	**0.47**	**1.97**	**0.46**	**1.03**	**0.37**	**15.33**
Spring:														
Mar	Max	35.41	34.14	36.04	34.51	35.81	34.78	35.40	34.18	35.10	33.47	32.33	33.10	41.6
	Min	32.42	33.35	33.31	33.84	33.54	34.19	33.68	33.68	33.53	33.06	31.91	32.73	20.5
	Diff	2.99	0.79	2.73	0.67	2.27	0.59	1.72	0.50	1.57	0.41	0.42	0.37	21.1
April	Max	52.86	46.32	55.20	46.66	54.62	46.57	54.62	46.54	54.25	45.77	43.85	40.39	56.6
	Min	42.36	44.15	43.42	44.86	43.75	45.12	44.23	45.27	44.32	44.78	41.35	39.83	35.2
	Diff	10.50	2.17	11.78	1.80	10.87	1.45	10.39	1.27	9.93	0.99	2.50	0.56	21.4
May	Max	65.64	57.83	67.48	58.19	67.64	58.47	67.30	57.77	67.28	57.23	61.48	55.44	67.2
	Min	53.63	55.65	54.88	56.39	54.99	56.67	55.60	56.47	55.53	56.32	58.00	55.13	45.1
	Diff	12.01	2.18	12.60	1.80	12.65	1.80	11.70	1.30	11.75	0.91	3.48	0.31	22.1
Seasonal	**Max**	**51.30**	**46.10**	**52.91**	**46.45**	**52.69**	**46.61**	**52.44**	**46.16**	**52.21**	**45.49**	**45.89**	**42.98**	**55.13**
	Min	**42.80**	**44.38**	**43.87**	**45.03**	**44.09**	**45.33**	**44.50**	**45.14**	**44.49**	**44.72**	**43.75**	**42.56**	**33.60**
	Diff	**8.50**	**1.72**	**9.04**	**1.42**	**8.60**	**1.28**	**7.94**	**1.02**	**7.72**	**0.77**	**2.14**	**0.42**	**21.53**
Summer:														
June	Max	78.36	69.30	81.21	70.49	81.96	70.65	82.36	69.46	82.61	68.62	74.45	65.16	81.5
	Min	65.28	66.70	67.03	68.42	67.18	68.18	67.94	67.83	67.80	67.58	69.28	64.88	53.7
	Diff	13.08	2.60	14.18	2.07	14.78	2.47	14.42	1.63	14.81	1.04	5.17	0.28	27.8
July	Max	83.29	75.18	84.93	76.08	85.44	75.63	85.43	74.62	85.54	73.98	78.94	71.83	83.0
	Min	70.74	72.87	71.76	74.31	71.67	73.70	72.19	73.31	72.02	73.10	74.08	71.54	58.5
	Diff	12.55	2.31	13.17	1.77	13.77	1.93	13.24	1.31	13.52	0.88	4.86	0.29	24.5
August	Max	81.53	74.08	83.14	75.18	83.57	74.76	83.29	73.77	83.30	73.29	77.30	71.93	81.1
	Min	68.50	71.73	69.49	73.36	69.43	72.73	70.05	72.49	69.74	72.32	72.72	71.53	57.6
	Diff	13.03	2.35	13.65	1.82	14.14	2.03	13.24	1.28	13.56	0.97	4.58	0.40	23.5
Seasonal	**Max**	**81.06**	**72.85**	**83.13**	**73.92**	**83.66**	**73.68**	**83.69**	**72.62**	**83.82**	**71.96**	**76.90**	**69.64**	**81.87**
	Min	**68.17**	**70.43**	**69.43**	**72.03**	**69.43**	**71.54**	**70.06**	**71.21**	**69.85**	**71.00**	**72.03**	**69.32**	**56.60**
	Diff	**12.89**	**2.42**	**13.70**	**1.89**	**14.23**	**2.14**	**13.63**	**1.41**	**13.97**	**0.96**	**4.87**	**0.32**	**25.27**
Autumn:														
September	Max	70.57	66.10	71.68	67.33	71.99	66.79	71.76	66.32	71.95	66.01	68.28	65.28	73.3
	Min	60.34	64.12	61.35	65.95	61.38	65.21	61.72	65.25	61.66	65.13	64.36	64.94	48.7
	Diff	10.23	1.98	10.33	1.38	10.61	1.58	10.04	1.07	10.29	0.88	3.92	0.34	24.6
October	Max	55.73	55.26	56.50	56.81	56.51	55.98	56.28	55.84	56.47	56.92	55.48	56.10	59.0
	Min	49.74	53.73	50.46	55.67	50.50	54.74	50.58	54.98	50.69	55.89	53.09	55.69	41.5
	Diff	5.99	1.53	6.04	1.14	6.01	1.24	5.70	0.86	5.78	1.03	2.39	0.41	17.5
November	Max	44.37	44.32	45.12	46.42	45.16	45.54	44.41	45.68	45.04	45.56	43.80	45.34	49.0
	Min	40.46	43.20	41.59	45.54	41.73	44.60	41.37	44.90	41.97	44.89	42.56	44.89	34.4
	Diff	3.91	1.12	3.53	0.88	3.43	0.94	3.04	0.78	3.07	0.67	1.24	0.45	14.6
Seasonal	**Max**	**56.89**	**55.23**	**57.77**	**56.85**	**57.89**	**56.10**	**57.48**	**55.95**	**57.82**	**56.16**	**55.85**	**55.57**	**60.43**
	Min	**50.18**	**53.08**	**51.13**	**55.72**	**51.20**	**54.85**	**51.22**	**55.04**	**51.44**	**55.30**	**53.34**	**55.17**	**41.53**
	Diff	**6.71**	**1.55**	**6.64**	**1.13**	**6.69**	**1.25**	**6.26**	**0.91**	**6.38**	**0.86**	**2.51**	**0.40**	**18.90**
Yearly	**Max**	**54.97**	**51.91**	**56.31**	**52.91**	**56.46**	**52.81**	**56.36**	**52.38**	**56.43**	**52.14**	**52.70**	**51.02**	**57.71**
	Min	**47.36**	**50.33**	**48.92**	**51.67**	**48.50**	**51.53**	**48.90**	**51.43**	**48.92**	**51.38**	**50.06**	**50.89**	**37.45**
	Diff	**7.61**	**1.58**	**7.93**	**1.24**	**7.96**	**1.28**	**7.46**	**0.95**	**7.51**	**0.76**	**2.64**	**0.13**	**20.26**

TABLE 85. MONTHLY, SEASONAL AND YEARLY MAXIMUM, MINIMUM AND AMPLITUDE OF TEMPERATURE OF SOILS WITH VARIOUS AMOUNTS OF ORGANIC MATTER.

1913–1914.		1.81% Org. Mat.		2.01% Org. Mat.		3.32% Org. Mat.		5.47% Org. Mat.		6.95% Org. Mat.		Peat.		Air.
		5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	
Winter:														
December..	Max......	37.00	39.56	37.85	41.65	37.78	40.81	37.42	41.16	37.97	41.80	38.99	41.97	39.1
	Min......	35.26	39.00	36.42	41.23	36.48	40.31	36.39	40.64	36.97	41.34	38.45	41.51	24.6
	Diff.......	1.74	0.56	1.43	0.42	1.30	0.50	1.03	0.52	1.00	0.46	0.54	0.46	14.5
January....	Max......	33.34	35.47	34.30	36.49	34.34	36.61	34.52	36.77	34.40	36.71	34.14	36.51	33.5
	Min......	32.93	35.20	33.92	36.19	33.97	36.35	34.12	36.53	33.98	36.51	33.99	36.35	20.5
	Diff.......	0.41	0.27	0.38	0.30	0.37	0.26	0.40	0.24	0.42	0.20	0.15	0.16	13.0
February...	Max......	32.43	35.10	33.52	36.02	33.81	36.28	34.22	36.56	34.51	36.67	34.64	36.47	23.5
	Min......	32.06	34.83	33.22	35.73	33.50	35.97	33.91	36.26	34.24	36.37	34.35	36.19	1.9
	Diff......	0.37	0.27	0.30	0.29	0.31	0.31	0.31	0.30	0.27	0.30	0.29	0.28	21.6
Seasonal...	**Max......**	**34.26**	**36.71**	**35.22**	**38.05**	**35.31**	**37.90**	**35.39**	**38.16**	**35.63**	**38.39**	**35.92**	**38.32**	**23.03**
	Min......	**33.42**	**36.34**	**34.52**	**37.72**	**34.65**	**37.54**	**34.81**	**37.81**	**35.06**	**38.07**	**35.60**	**38.02**	**15.67**
	Diff.......	**0.84**	**0.37**	**0.70**	**0.33**	**0.66**	**0.36**	**0.58**	**0.35**	**0.57**	**0.32**	**0.32**	**0.30**	**16.36**
Spring:														
March.....	Max......	37.00	36.50	37.96	37.03	37.91	37.37	38.04	37.48	37.87	37.35	34.99	35.98	39.7
	Min......	33.70	35.77	35.20	36.49	35.20	36.76	35.56	37.03	35.63	36.97	34.55	35.74	22.5
	Diff.......	3.30	0.73	2.76	0.54	2.71	0.61	2.48	0.45	2.24	0.38	0.44	0.24	17.2
April.......	Max......	51.13	46.07	51.68	45.77	51.79	45.63	50.77	45.32	50.23	44.87	46.61	42.92	55.2
	Min......	42.11	44.00	43.33	44.35	43.28	44.54	43.73	44.36	43.87	44.14	44.22	42.56	34.2
	Diff.......	9.02	2.07	8.35	1.42	8.51	1.09	7.04	0.96	6.36	0.73	2.39	0.36	21.0
May.......	Max......	67.53	58.80	68.68	58.30	68.63	58.77	68.27	57.77	68.08	57.07	61.81	54.75	70.6
	Min......	53.68	55.92	54.71	56.09	54.53	56.38	54.92	56.12	54.96	55.93	57.32	54.37	46.5
	Diff.......	13.85	2.88	13.97	2.21	14.10	1.39	13.35	1.65	13.12	1.14	4.49	0.38	24.1
Seasonal...	**Max......**	**51.89**	**47.12**	**52.77**	**47.03**	**52.78**	**47.26**	**52.36**	**46.86**	**52.06**	**46.43**	**47.80**	**44.55**	**55.17**
	Min......	**43.16**	**45.23**	**44.41**	**45.64**	**44.34**	**45.89**	**44.74**	**45.80**	**44.82**	**45.68**	**45.36**	**44.22**	**34.40**
	Diff......	**8.73**	**1.89**	**8.36**	**1.39**	**8.34**	**1.37**	**7.62**	**1.06**	**7.24**	**0.75**	**2.44**	**0.33**	**20.77**
Summer:														
June........	Max......	76.45	68.78	80.37	69.50	80.65	70.21	81.01	69.42	81.11	68.88	74.72	66.71	77.6
	Min......	64.12	66.32	66.33	67.33	66.23	67.83	66.67	67.67	66.79	67.60	69.74	66.24	54.3
	Diff.......	12.33	2.46	14.04	2.17	14.42	2.38	14.34	1.75	14.32	1.28	4.98	0.47	23.2
July........	Max......	81.73	73.80	84.06	73.70	84.13	74.36	84.72	73.60	84.92	73.02	78.81	70.84	83.0
	Min......	69.36	71.06	70.95	71.48	70.66	71.93	71.17	71.76	71.63	71.77	74.01	70.55	59.0
	Diff.......	12.37	2.74	13.11	2.22	13.47	2.43	13.55	1.84	13.29	1.25	4.80	0.29	24.0
August.....	Max......	77.76	72.24	80.65	72.17	79.83	72.89	79.60	72.21	79.68	72.02	75.63	70.95	81.0
	Min......	66.54	69.96	68.66	70.74	68.01	70.98	68.33	70.88	68.50	71.06	71.65	70.61	57.0
	Diff.......	11.22	2.28	11.99	1.43	11.82	1.91	11.27	1.33	11.18	0.96	3.98	0.34	24.0
Seasonal...	**Max......**	**78.65**	**71.61**	**81.69**	**71.79**	**81.54**	**72.49**	**81.78**	**71.74**	**81.90**	**71.31**	**76.39**	**69.50**	**80.53**
	Min.......	**66.67**	**69.11**	**68.65**	**69.85**	**68.30**	**70.25**	**68.72**	**70.10**	**68.97**	**70.14**	**71.80**	**69.13**	**56.77**
	Diff.......	**11.98**	**2.50**	**13.04**	**1.94**	**13.24**	**2.24**	**13.06**	**1.64**	**12.93**	**1.17**	**4.59**	**0.37**	**23.76**
Autumn:														
September..	Max......	68.24	64.74	70.26	65.02	69.91	65.33	70.10	64.98	70.11	64.97	66.36	64.18	72.0
	Min......	57.34	62.38	59.22	63.28	58.71	63.47	59.21	63.68	59.34	64.02	62.92	63.76	48.0
	Diff.......	10.90	2.36	11.04	1.74	11.20	1.86	10.89	1.30	10.77	0.95	3.44	0.42	24.0
October....	Max......	59.17	57.55	60.42	57.91	59.94	58.18	60.22	58.22	60.33	58.37	58.19	58.10	65.0
	Min......	51.12	55.62	52.67	56.64	52.54	56.69	52.96	57.22	53.21	57.48	55.61	57.69	44.0
	Diff.......	8.05	1.93	7.75	1.27	7.40	1.49	7.26	1.00	7.12	0.89	2.58	0.41	21.0
November..	Max......	40.34	42.86	41.76	43.72	41.76	43.94	41.94	44.25	41.96	44.72	41.81	44.89	47.0
	Min......	37.13	41.52	38.67	42.80	38.61	43.03	38.98	43.54	39.14	44.10	40.52	44.55	28.0
	Diff.......	3.21	1.34	3.09	0.92	3.15	0.91	2.96	0.71	2.82	0.62	1.29	0.34	19.0
Seasonal...	**Max......**	**55.92**	**55.05**	**57.48**	**55.55**	**57.20**	**55.82**	**57.42**	**55.82**	**57.47**	**56.02**	**55.45**	**55.72**	**61.33**
	Min......	**48.53**	**53.17**	**50.19**	**54.24**	**49.95**	**54.40**	**50.38**	**54.81**	**50.56**	**55.20**	**53.02**	**55.33**	**40.00**
	Diff.......	**7.39**	**1.88**	**7.29**	**1.31**	**7.25**	**1.42**	**7.04**	**1.01**	**6.91**	**0.82**	**2.43**	**0.39**	**21.33**
Yearly.....	**Max......**	**55.18**	**52.62**	**56.79**	**53.11**	**56.71**	**53.37**	**56.74**	**53.15**	**56.77**	**53.04**	**53.89**	**52.02**	**58.27**
	Min......	**47.95**	**50.96**	**49.44**	**51.86**	**49.31**	**52.02**	**49.66**	**52.13**	**49.85**	**52.27**	**51.45**	**51.68**	**36.71**
	Diff....	**7.23**	**1.66**	**7.35**	**1.25**	**7.40**	**1.35**	**7.08**	**1.02**	**6.92**	**0.77**	**2.44**	**0.34**	**21.56**

TABLE 86.—MONTHLY, SEASONAL, AND YEARLY MAXIMUM, MINIMUM AND AMPLITUDE OF TEMPERATURE OF SOILS WITH VARIOUS AMOUNTS OF ORGANIC MATTER.

1914–1915.		1.81% Org. Mat.		2.01% Org. Mat.		3.32% Org. Mat.		5.47% Org. Mat.		6.95% Org. Mat.		Peat.		Air.
		3″	6″	3″	6″	3″	6″	3″	6″	3″	6″	3″	6″	
Winter:														
December	Max.	32.21	33.69	33.44	34.30	33.69	34.79	33.97	34.70	34.44	35.20	35.03	35.71	28.0
	Min.	30.44	32.98	31.53	33.67	32.38	34.25	32.95	34.30	33.83	34.91	34.69	35.45	15.0
	Diff.	1.77	0.71	1.91	0.63	1.31	0.54	1.02	0.40	0.61	0.29	0.34	0.26	13.0
January	Max.	30.62	31.65	31.78	32.63	32.39	33.34	32.77	33.34	32.97	33.54	32.89	32.88	28.0
	Min.	29.98	31.32	31.37	32.39	32.02	33.14	32.49	33.20	32.79	33.40	32.70	32.70	12.9
	Diff.	0.64	0.33	0.41	0.24	0.37	0.20	0.28	0.14	0.18	0.14	0.11	0.18	15.1
February	Max.	32.46	33.05	33.46	33.73	33.45	34.06	33.72	33.91	33.61	33.91	32.76	32.41	36.2
	Min.	30.75	32.33	32.23	33.31	32.66	33.66	32.70	33.36	32.93	33.45	32.48	32.30	22.5
	Diff.	1.71	0.72	1.23	0.42	0.79	0.40	1.02	0.55	0.68	0.46	0.28	0.11	13.7
Seasonal	**Max.**	**31.76**	**32.80**	**32.89**	**33.55**	**33.18**	**34.06**	**33.49**	**33.98**	**33.67**	**34.22**	**33.56**	**33.67**	**30.73**
	Min.	**30.39**	**32.21**	**31.71**	**33.12**	**32.35**	**33.68**	**32.71**	**33.62**	**33.18**	**33.92**	**33.29**	**33.48**	**16.80**
	Diff.	**1.37**	**0.59**	**1.18**	**0.43**	**0.83**	**0.38**	**0.78**	**0.36**	**0.49**	**0.30**	**0.27**	**0.19**	**13.93**
Spring:														
March	Max.	36.71	36.98	37.81	37.48	37.40	37.48	37.04	36.79	37.02	36.88	32.76	32.32	39.6
	Min.	30.52	33.01	31.71	33.63	32.21	33.95	32.86	34.06	33.26	34.49	32.38	32.15	20.6
	Diff.	6.19	3.97	6.10	3.85	5.19	3.53	4.18	2.73	3.76	2.39	0.38	0.17	19.0
April	Max.	60.69	57.83	63.15	58.53	62.28	58.89	61.20	57.74	60.32	56.67	52.52	46.66	63.0
	Min.	45.64	47.08	46.41	47.57	46.35	47.74	46.82	47.80	46.73	48.56	45.64	45.23	40.1
	Diff.	15.05	10.75	16.74	10.96	15.93	11.15	14.38	9.94	13.59	8.11	6.88	1.43	22.9
May	Max.	62.09	60.32	66.09	62.46	64.99	62.22	64.14	61.22	63.79	61.06	60.05	54.56	62.3
	Min.	47.98	50.27	49.07	50.96	48.86	50.91	49.58	51.10	49.53	52.38	51.38	52.90	40.7
	Diff.	14.11	10.05	17.02	11.50	16.13	11.31	14.56	10.12	14.26	8.68	8.67	1.66	21.6
Seasonal	**Max.**	**53.16**	**51.71**	**55.68**	**52.82**	**54.89**	**52.86**	**54.13**	**51.92**	**53.71**	**51.54**	**48.44**	**44.51**	**54.97**
	Min.	**41.38**	**43.45**	**42.40**	**44.05**	**42.47**	**44.20**	**43.09**	**44.32**	**42.84**	**45.14**	**43.13**	**43.43**	**33.80**
	Diff.	**11.78**	**8.26**	**13.28**	**8.77**	**12.42**	**8.66**	**11.04**	**7.60**	**10.87**	**6.40**	**5.31**	**1.08**	**21.17**
Summer:														
June	Max.	74.71	71.20	77.71	72.78	76.90	73.06	75.92	72.00	75.99	71.11	71.09	63.51	72.7
	Min.	56.62	58.88	57.55	59.42	57.36	59.33	57.92	59.59	57.90	60.12	59.62	61.36	49.3
	Diff.	18.09	12.32	20.16	13.36	18.54	13.73	18.00	12.41	18.09	10.99	11.47	2.15	23.4
July	Max.	79.19	76.45	83.73	78.79	82.60	78.99	82.26	78.21	81.77	76.96	77.77	70.15	77.9
	Min.	62.90	65.02	64.37	65.87	64.21	65.84	64.63	65.82	64.66	66.36	65.77	67.82	57.9
	Diff.	16.29	11.43	19.36	12.92	18.39	13.15	17.63	12.39	17.11	10.60	12.00	2.33	20.0
Aug.	Max.	74.80	72.82	78.14	74.22	77.16	74.72	76.87	73.86	76.37	72.90	73.28	67.57	73.3
	Min.	59.93	62.87	61.24	63.47	61.15	63.72	61.81	63.71	61.71	64.29	63.48	65.76	53.6
	Diff.	14.87	9.95	16.90	10.75	16.01	11.00	15.06	10.15	14.66	8.61	9.80	1.81	19.7
Seasonal	**Max.**	**76.23**	**73.49**	**79.86**	**75.26**	**78.89**	**75.59**	**78.35**	**74.69**	**78.04**	**73.66**	**74.05**	**67.08**	**74.63**
	Min.	**59.82**	**62.26**	**61.05**	**62.92**	**60.91**	**62.96**	**61.45**	**63.04**	**61.42**	**63.59**	**62.96**	**64.98**	**53.60**
	Diff.	**16.41**	**11.23**	**18.81**	**12.34**	**17.98**	**12.63**	**16.90**	**11.65**	**16.62**	**10.07**	**11.09**	**2.10**	**21.03**
Autumn:														
September	Max.	73.16	70.24	75.98	71.49	74.93	71.81	74.40	71.05	73.64	70.02	70.21	64.52	73.8
	Min.	57.12	59.80	58.05	60.21	58.04	60.45	58.92	60.60	58.80	61.28	60.54	62.58	52.6
	Diff.	16.04	10.44	17.93	11.28	16.89	11.36	15.48	10.45	14.84	8.74	9.67	1.94	21.2
October	Max.	57.63	56.00	59.92	56.90	59.11	57.57	59.28	57.13	58.53	56.66	55.92	52.16	61.2
	Min.	46.48	48.65	47.52	48.92	47.42	49.30	48.26	49.38	47.99	49.84	48.82	50.27	41.0
	Diff.	11.15	7.35	12.40	7.98	11.69	8.27	11.02	7.75	10.54	6.82	7.10	1.89	20.2
November	Max.	43.50	43.55	45.43	44.18	44.84	44.62	45.05	44.46	44.79	44.38	43.38	42.71	47.4
	Min.	37.39	39.97	38.69	40.44	38.72	40.77	39.47	40.94	39.55	41.40	40.55	41.81	32.1
	Diff.	6.11	3.58	6.74	3.74	6.12	3.85	5.58	3.52	5.24	2.98	2.83	0.90	15.3
Seasonal	**Max.**	**58.10**	**56.60**	**60.44**	**57.52**	**59.63**	**58.00**	**59.58**	**57.55**	**58.99**	**57.02**	**56.50**	**53.13**	**60.80**
	Min.	**47.00**	**49.47**	**48.09**	**49.86**	**48.06**	**50.17**	**48.88**	**50.31**	**48.78**	**50.84**	**49.97**	**51.55**	**41.90**
	Diff.	**11.10**	**7.13**	**12.35**	**7.66**	**11.57**	**7.83**	**10.70**	**7.24**	**10.21**	**6.18**	**6.53**	**1.58**	**18.90**
Yearly	**Max.**	**54.81**	**53.65**	**57.22**	**54.79**	**56.65**	**55.13**	**56.39**	**54.54**	**56.10**	**54.11**	**53.14**	**49.60**	**55.28**
	Min.	**44.65**	**46.85**	**45.81**	**47.49**	**45.95**	**47.75**	**46.53**	**47.82**	**46.56**	**48.37**	**47.34**	**48.36**	**36.53**
	Diff.	**10.16**	**6.80**	**11.41**	**7.30**	**10.70**	**7.38**	**9.86**	**6.72**	**9.54**	**5.74**	**5.80**	**1.24**	**18.75**

The chief and most important facts revealed by the preceding tables may be summarized as follows: (1) The magnitude of the fluctuation was very small in winter in all soils and at all depths. After the soils thawed, however, it began to increase until it reached a maximum in June and July and then commenced to decrease again until winter. (2) At the 18-inch depth the degree of amplitude was very small throughout the year in all soils but especially in peat. At the 3, 5 and 6-inch depths, however, it was very high and about the same during the summer months in all the soils having various percentages of organic matter, but quite lower in peat. (3) The minimum temperature attained was highest in peat, slightly less and about the same in the various soils treated with peat, and lowest in the untreated sand. While the maximum was greatest and practically equal in the treated soils, slightly smaller in the untreated sand, and still smaller in peat, the variations, both for the minimum and maximum were not very large. (4) The amplitude of the air temperature was considerably higher than that of all soils at any depth.

ADDITIONAL EXPERIMENTAL DATA ON THE TEMPERATURE OF CULTIVATED, UNCULTIVATED AND SOD SOIL.

PLAN OF THE EXPERIMENT.

A correct knowledge of the effect of cultural methods, such as cultivation, uncultivation and sod, upon the soil temperature is of great interest and importance both from the scientific as well as from the practical standpoint. The current information concerning the effect of these cultural methods upon soil temperature is limited and unsatisfactory. Consequently, in November, 1911, at the time that the foregoing series of experiments were started, a systematic and thorough investigation of this problem was also instituted. The research consisted of measuring the temperature of soil under the above conditions by means of thermographs[5]. It was thought and hoped that by the use of such instruments, which make continuous records, very definite and extremely important information would be procured upon the subject. Unfortunately, however, these instruments proved to be a failure, as the bulbs containing the liquid medium would always leak in spite of many precautionary measures taken and the numerous repairs made. It seems that the joints between the tube and the hollow wire would corrode in the soil and allow the liquid to escape. After employing these instruments, seven in number, three double and two single, for two years they were abandoned because the data obtained by them could not be relied upon. They were replaced, however, by soil mercury thermometers graduated to 0.5°F. Only two years' data have been secured by the latter instruments. During the year 1913 the temperature was measured at 7-inch depth, three times a day as usual. During 1915, however, it was recorded at 3 and 6-inch depths. In Table 87 are presented the monthly maximum, minimum, amplitude and average temperature of the soil under the various cultural conditions during the two years.

It should be stated that the uncultivated plot was kept undistributed but free of weeds; the cultivated plot was stirred almost always after a rain; the vegetation of the sod land consisted of alfalfa and grass and was never cut throughout the four years.

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[5] Obtained from Frietz, Baltimore, Md.

TABLE 87.—MAXIMUM, MINIMUM, AMPLITUDE AND AVERAGE TEMPERATURE OF UNCULTIVATED, CULTIVATED AND SOD SOIL.

1913.		April.				May.				June.				July.			
		Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
Uncultivated....	7"	49.17	41.39	7.78	45.73	60.14	51.85	8.29	56.48	73.39	62.81	10.48	68.61	80.36	69.49	10.87	75.12
Cultivated......	7"	47.80	41.80	6.00	44.96	59.62	53.23	6.39	56.51	72.81	64.38	7.43	68.58	77.84	70.22	7.62	73.91
Sod..........	7"	46.55	43.10	3.45	44.81	55.62	52.52	3.10	54.16	62.82	59.49	3.33	61.62	68.38	65.51	2.87	66.92

1913.		August.				September.				October.				November.			
		Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
Uncultivated.....	7"	77.49	67.84	9.65	72.80	66.87	59.99	6.88	63.67	53.58	49.58	4.00	51.72	42.27	39.74	2.53	41.11
Cultivated.......	7"	75.82	67.48	8.34	71.78	66.50	60.37	6.13	63.46	53.86	49.94	3.82	52.03	43.25	40.59	2.66	41.94
Sod.............	7"	68.49	66.04	2.45	67.26	60.42	58.53	1.89	59.50	52.78	51.31	1.47	52.06	43.15	41.77	1.38	42.46

1914-1915.		December.				January.				February.				March.			
		Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
Uncultivated.....	3"	33.09	31.92	1.17	32.53	31.51	31.11	0.40	31.30	31.83	30.70	1.13	31.34	34.83	31.29	3.54	33.23
Cultivated.......	3"	33.96	33.26	0.70	33.64	32.91	32.59	0.32	32.75	33.35	32.49	0.86	32.97	34.67	32.11	2.56	33.52
Sod.............	3"	35.59	35.34	0.25	35.46	34.82	34.55	0.27	34.70	33.85	33.52	0.33	33.69	33.48	32.78	0.70	33.15

		April.				May.				June.				July.			
		Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
Uncultivated.....	3"	58.66	44.90	13.76	53.34	61.42	48.79	12.63	56.68	72.32	56.93	15.40	66.55	78.41	64.07	14.34	73.07
Uncultivated.....	6"	.....	.....	.....	.....	60.38	50.53	9.85	56.45	70.56	59.12	11.44	65.90	76.62	66.03	10.59	72.32
Cultivated.......	3"	56.38	45.55	10.83	52.15	59.34	49.42	9.92	55.91	69.53	57.40	12.13	64.94	75.78	64.20	11.58	71.33
Cultivated.......	6"	.....	.....	.....	.....	58.53	51.92	6.61	55.64	67.84	59.60	8.24	64.38	73.86	66.19	7.67	70.66
Sod.............	3"	49.48	44.81	4.67	47.41	53.88	50.37	3.51	52.42	61.13	57.05	4.08	59.56	69.40	64.08	5.32	67.44
Sod.............	6"	.....	.....	.....	.....	53.07	50.96	2.11	52.13	60.04	57.97	2.07	59.07	67.62	64.67	2.95	66.24

		August.				September.				October				November.			
		Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
Uncultivated.....	3"	73.12	60.63	12.49	68.52	70.44	58.00	12.44	65.57	55.88	47.23	8.65	52.26	42.90	38.02	4.88	40.70
Uncultiavted.....	6"	72.34	63.43	8.91	68.81	69.18	60.74	8.44	65.81	54.90	49.28	5.62	52.73	42.91	40.19	2.72	41.78
Cultivated.......	3"	72.12	61.49	10.63	68.15	69.41	58.62	10.79	65.26	54.68	48.10	6.58	52.20	42.89	39.03	3.86	41.26
Cultivated.......	6"	70.73	64.08	6.65	67.84	67.91	61.12	6.79	65.09	54.52	50.07	4.45	52.60	43.37	41.05	2.32	42.35
Sod.............	3"	67.07	62.52	4.55	65.34	64.67	60.17	4.50	62.92	53.22	50.38	2.84	52.11	43.70	41.71	1.99	42.84
Sod.............	6"	65.82	63.92	1.90	64.97	63.24	61.32	1.92	62.36	53.01	51.53	1.48	52.32	44.18	43.10	1.08	43.62

Table 87 shows (1) that the average temperature of the sod soil at 7 inches depth was about the same or only slightly lower than that of the cultivated and uncultivated, during the month of April. From this month on, the sod plot began to have decidely lower temperature than the other plots and continued to be colder until October. The highest variation occurred in June and July when the average temperature of the sod land was about 6 or 7°F lower than that of the bare land. These differences, however, commenced to become smaller in August and by September they had practically disappeared. In October the order of magnitude was reversed, the sod plot became warmer than the other two plots and continued to have a higher temperature until freezing and even during the winter months. The data for the winter months for this year are not included in the above table on account of incompleteness but they are on file and show that as a monthly average the temperature of the sod plot remained about 2°F higher than that of the cultivated and uncultivated plots.

(2) During the months of April, May and June the average temperature of the uncultivated and cultivated soil was practically equal. During July and August, however, the uncultivated plot was about 1°F warmer than the cultivated, but during September, October, and November and also during the winter months they had again equal temperature.

(3) The degree of amplitude was highest in the uncultivated plot, slightly smaller in the cultivated, and very small in the sod. Thus, for instance, in July it amounted to 10.87° in the uncultivated plot, 7.62° in the cultivated, and only 2.87°F in the sod.

(4) As a rule the uncultivated plot had a slightly higher maximum temperature than the cultivated, but the latter kept a slightly higher minimum than the former. The magnitude of the maximum and minimum of the sod plot was practically equal to that of the other plots in the early spring and fall; in the summer it was far below, but in the winter somewhat higher.

Table 87 contains also the monthly maximum, minimum, amplitude and average temperature of the same plots during the year of 1915 but at different depths—3 and 6 inches. The data in this table reveal exactly the same principles as the preceding and consequently need no further discussion.

The daily march of temperature which is not included here on account of lack of space, indicates (1) that in the spring all the three plots thawed practically simultaneously, (2) The temperature of the cultivated and uncultivated plots would rise quicker and higher whenever the air temperature rose very rapidly and suddenly than that of the sod. The converse of this was also true. (3) As between the cultivated and uncultivated the rate of rising and falling of temperature was somewhat similar to that of the sod, but to less degree, of course.

Tihs investigation, therefore, proves two very important facts. (1) A soil with compacted or undisturbed surface is only slightly warmer, about 1°F, than a cultivated soil, and that is only in the summer months and possibly in the spring; in the fall and winter months both soils are equally warm. (2) A soil covered with a growing or dead vegetation has a slightly lower temperature in the spring, considerably lower in the summer, but slightly higher in the fall and appreciably higher in the winter than the bare soils. The vegetation cover, therefore, has both a cooling and warming effect upon the soil in opposite direction to the air temperature of the season.

The slightly higher temperature of the uncultivated soil over the cultivated during the summer and possibly in the spring, is due chiefly to the dry mulch formed on the cultivated soil. This dry mulch forms rather poor and imperfect connections with the lower layers of the soil and the heat energy which it receives from the sun is not all conducted downward rapidly but a large amount of it is allowed to accumulate on the surface of this mulch and then some of it is radiated back to the atmosphere, while on account of the compacted condition and consequently better heat conducting power a greater amount of heat is propogated to the lower depths in the case of the uncultivated soil and not so much accumulates at the surface and then radiated into space. These facts were experimentally proved by the following series of experiments. The bulbs of mercury thermometers were placed one inch above the surface of both the cultivated and uncultivated soils. It was found that the thermometer over the cultivated soil would register at certain days about 10°F higher temperature than that placed over the uncultivated soil. In another experiment the bulbs of the thermometers were placed horizontally over the surface of both soils. It was discovered also in this case that the surface of the cultivated soil would be 7 or 8°F warmer in certain days than that of the uncultivated.

This same mulch, however, for the same reason that it reduces somewhat the amount of heat penetrating the lower depths during the insolation, diminishes equally well the quantity of heat that is lost during the night.

The dry mulch then tends to act as a blanket analogous to that of vegetation cover, but to a less degree. It is perhaps due to this mulch and also to the slightly higher moisture content that the temperature of the cultivated soil rises or falls somewhat less rapidly than that of the uncultivated.

The cooling and warming effect of the cover crop in both the warm and cold seasons of the year is self-evident. In the summer time the growing crop keeps the soil temperature low for the following reasons: (1) Practically all the sun rays are intercepted by the growing vegetation so that the surface ground is nearly all shaded and its temperature rise is dependent upon the wind and convection currents and conduction, and not upon any direct heat absorption. (2) The air temperature around the plants and at the surface of the soil is low on account of the great amount of transpiration and some evaporation that take place. Both of these processes have, of course, a tremendous influence upon the soil temperature.

In the cold part of the year the dead or partially decayed vegetation acts as a blanket over the surface soil. This cover performs several functions chief which are: (1) The prevention of the cold currents of air from coming in contact with the surface soil and thereby cooling it, and (2) the layer of vegetation is porous and the spaces are filled with air. This air being a very poor conductor of heat does not transmit very rapidly heat from the soil to the air above and vice versa and as a result the soil loses its heat less rapidly than if it were unprotected.

It is through the vegetation cover that is afforded probably one of the most efficient and expedient means of preventing extreme low soil temperature in the winter which would be detrimental to vegetation. A vegetation cover coupled with snow certainly forms a very powerful soil temperature protector.

EFFECT OF SNOW ON THE SOIL TEMPERATURE.

From the theoretical standpoint a layer of snow ought to protect the soil against very severe cold weather and keep its temperature higher and steadier. Its effect would seem to be analogous to that of a vegetation cover. It ought to act as a blanket and reduce the rapid loss of heat firstly by preventing the convection and wind currents from coming in contact with the surface soil, and secondly, on account of its poor heat conductivity.

When the thickness of the layer is rather large, snow is certainly a most efficient agent in protecting the soil from very low temperature. Observations have been made upon the subject through four successive winters and the results obtained are exceedingly interesting and of great practical importance. Some of these results have already been published in the previous report. In the present paper will be presented only the data collected during the month of January 1915. The observations conducted during this year consisted of noting the temperature of soil at 3 inches deep under the following conditions: (1) bare, (2) covered with compacted snow, (3) covered with uncompacted snow, and (4) covered with layer of vegetation and uncompacted snow. Table 88 contains the daily and monthly maximum, minimum, amplitude, and average temperature for the month of January.

TABLE 88.—EFFECT OF SNOW COVER ON SOIL TEMPERATURE, JANUARY, 1915.

		Daily Maximum-Minimum.					Daily Average.				Air.		
		Bare.	Compacted.	Uncompacted.	Uncompacted and vegetation.		Bare.	Compacted.	Uncompacted.	Uncompacted and vegetation.	Maxmimum.	Minimum.	Average.
2	Max...........	29.8	30.9	31.7	35.4	2....	29.60	30.80	31.60	35.30	26	1	14
	Min...........	29.3	30.7	31.5	35.2								
4	Max...........	29.0	30.2	31.8	35.5	4....	27.37	29.73	31.67	35.37	33	17	25
	Min...........	24.2	29.1	31.5	35.3								
5	Max...........	31.9	31.4	32.0	35.7	5....	30.60	31.20	31.87	35.93	41	27	34
	Min...........	28.8	30.8	31.7	35.4								
6	Max...........	32.3	32.0	32.0	35.7	6....	32.20	31.93	32.00	35.63	39	33	36
	Min...........	32.1	31.8	32.0	35.5								
7	Max...........	32.3	32.3	32.0	35.3								
	Min...........	31.3	32.3	32.0	35.2	7....	31.83	32.30	32.00	35.27	34	21	28
8	Max...........	29.5	32.3	32.1	35.4								
	Min...........	27.5	32.1	32.0	35.2	8....	28.70	32.20	32.03	35.30	26	19	22
9	Max...........	28.6	31.5	32.0	35.4								
	Min...........	24.8	31.2	31.8	35.1	9....	27.07	31.30	31.87	35.27	23	15	19
11	Max...........	31.8	31.9	32.2	35.5								
	Min...........	29.7	31.2	32.0	35.4	11....	30.90	31.63	32.07	35.43	36	30	33
12	Max...........	31.4	32.0	32.0	35.4								
	Min...........	30.8	3.18	31.9	35.2	12....	31.03	31.87	31.97	35.30	33	27	30
13	Max...........	30.9	31.6	32.0	35:3								
	Min...........	28.4	31.0	31.8	35.2	13....	30.03	31.33	31.93	35.27	33	22	28
14	Max...........	31.8	31.8	32.1	35.6								
	Min...........	28.2	31.0	31.9	35.2	14....	30.47	31.53	32.00	35.40	36	27	32
15	Max...........	31.9	31.9	32.3	35.5								
	Min...........	28.8	31.1	31.9	35.2	15....	30.77	31.63	32.07	35.37	35	25	30
16	Max...........	32.0	32.1	32.2	35.3								
	Min...........	28.9	31.0	31.9	35.3	16....	30.77	31.63	32.03	35.30	41	24	32
18	Max...........	30.3	31.3	31.8	35.0								
	Min...........	29.4	30.9	31.5	34.9	18....	29.90	31.13	31.60	34.97	26	24	25
19	Max...........	31.0	31.4	32.0	35.1								
	Min...........	29.8	30.8	31.6	34.9	19....	30.27	31.10	31.77	35.00	27	18	22
20	Max...........	30.3	30.9	32.0	35.2								
	Min...........	26.7	29.9	31.5	35.0	20....	28.50	30.40	31.75	35.10	29	8	18
21	Max...........	29.0	30.2	31.7	35.0								
	Min...........	25.2	29.4	31.0	34.7	21....	26.73	29.67	31.37	34.87	21	9	15
22	Max...........	24.7	28.8	31.2	34.7								
	Min...........	20.0	28.3	31.1	34.4	22....	22.20	28.60	31.10	34.57	14	8	11
23	Max...........	27.40	29.4	31.4	34.3								
	Min...........	22.9	28.4	31.0	34.0	23....	25.63	28.83	31.13	34.17	30	—3	8
25	Max...........	27.2	28.2	31.2	33.7								
	Min...........	20.2	26.6	30.6	33.4	25....	24.50	27.57	30.93	33.53	27	13	20
26	Max...........	26.5	26.9	31.0	33.8								
	Min...........	18.0	25.7	30.2	33.3	26....	22.93	26.30	30.53	33.47	23	5	14
27	Max...........	25.1	25.8	30.6	33.5								
	Min...........	17.8	23.0	29.9	33.0	27....	22.03	24.77	30.33	33.23	25	7	16
28	Max...........	23.7	23.0	29.9	33.3								
	Min...........	18.8	22.0	29.4	32.8	28....	20.83	22.67	29.57	33.00	10	—6	2
29	Max...........	20.0	22.3	29.6	33.0								
	Min...........	14.5	20.8	29.0	32.5	29....	17.10	21.37	29.20	32.73	13	—13	0
30	Max...........	21.2	21.1	28.8	32.8								
	Min...........	7.5	15.6	27.0	32.3	30....	16.27	18.37	27.90	32.60	18	—13	2
Ave.	**Max.......**	**28.79**	**29.65**	**31.51**	**34.82**								
	Min.......	**24.95**	**28.66**	**31.11**	**34.55**	**Ave...**	**27.13**	**29.20**	**31.30**	**34.70**	**27.96**	**13.80**	**20.64**
	Range......	**3.84**	**0.99**	**0.40**	**0.27**								

From an examination of the above table it will be seen that as a monthly average the soils covered with snow had a higher temperature than the bare. Indeed, the soil covered with the uncompacted snow and layer of vegetation did not freeze and its temperature was about 7°F higher than that of the bare, while the plots with the compacted and uncompacted snow were about 2 and 4°F warmer, respectively.

The daily records show that whenever the air temperature fell very low that of the bare soil also would go down many degrees lower than that of the other soils. Thus, for instance, on January 30, which was a cold day the average temperature ranged as follows in the various plots: bare 16.27°, compacted 18.37°, uncompacted 27.90°, and uncompacted with vegetation 32.60°F. While the minimum temperature for the same day ran as follows: bare 7.5°, compacted 15.60°, uncompacted 27.0°, and uncompacted with vegetation 32.2°F. The influence, therefeore, of snow upon soil temperature in the winter is very great.

EFFECT OF TOPOGRAPHIC POSITION ON SOIL TEMPERATURE.

Considerable is already known concerning the effect of topographic position on soil temperature. Since, however, it was resolved to investigate the general subject of soil temperature as systematically and thoroughly as possible in order to arrive at definite and safe conclusions, a study of this phase was also conducted. This part of the investigation consisted in making observations on soil temperature at various topographic positions, namely, at a south slope, north slope, top of a hill, at a river bank, and at a low land. All these points were located within a small area. The river was situated between the north and south slope. The altitude and angle of these slopes were of medium magnitude. The altitude of the hill, which was the top of the north slope was also comparatively small. The soil of the low land was muck, that of the other locations was a sandy loam. The temperature was recorded three times a day, daily except Sunday, at 3 inches depth, by means of soil mercury thermometers. The surface of all these soils was kept free from vegetation. The data obtained from this series of observations are presented in Table 89. On account of limited space only the monthly maximum, minimum, amplitude and average temperature are given.

TABLE 89.—MONTHLY, MAXIMUM, MINIMUM, AMPLITUDE AND AVERAGE TEMPERATURE OF SOIL AT VARIOUS TOPOGRAPHIC POSITIONS.

1915.	March.				April.				May.			
	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
South Slope..........	40.15	34.84	5.31	37.24	56.89	47.29	9.60	52.32	61.28	52.78	8.50	57.42
River Bank..........	34.02	33.02	1.00	33.44	49.99	45.27	4.72	47.33	54.75	49.82	4.93	52.42
North Slope..........	37.28	33.88	3.40	35.39	55.00	46.64	8.36	50.93	58.44	51.44	7.00	55.11
High Point..........	36:89	33.81	3.08	35.29	53.71	45.36	8.35	50.14	58.77	50.80	7.97	55.10
Low land..........	34.33	33.51	0.82	33.91	47.28	45.25	2.03	46.24	54.82	52.27	2.55	53.69

1915.	June.				July.				August.			
	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
South Slope..........	73.18	59.44	13.74	67.27	79.10	66.67	12.43	73.89	73.67	62.35	11.32	69.28
River Bank..........	62.82	56.18	6.64	59.92	69.06	63.77	5.29	66.84	65.30	60.62	4.68	63.36
North Slope..........	70.86	59.21	11.65	65.82	75.77	66.11	9.66	71.78	71.37	62.65	8.72	68.00
High Point..........	72.38	58.73	13.65	66.44	76.59	65.82	10.77	72.24	72.78	61.55	11.23	67.92
Low land..........	67.45	58.85	8.60	63.64	74.11	66.28	7.83	70.59	73.26	63.56	9.70	69.41

1915.	September.				October.				November.			
	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
South Slope..........	69.96	58.44	11.52	65.41	56.53	46.83	9.70	52.37	43.54	38.59	4.95	41.44
River Bank..........	63.10	59.90	3.20	60.58	54.85	47.35	7.50	51.82	43.56	38.99	4.57	41.26
North Slope..........	69.00	58.53	10.47	64.94	57.10	47.32	9.78	52.86	43.67	38.63	5.04	41.56
High Point..........	69.70	57.50	12.20	64.60	54.77	46.08	8.69	51.07	43.69	38.31	5.38	41.06
Low land..........	69.60	59.96	9.64	65.56	53.62	47.34	6.28	50.90	41.70	38.11	3.59	40.02

An inspection of the foregoing table shows that from March up to about September the average temperature of the south slope was about 2°F higher than that of the north and top hill, about 5 or 6°F than that of the river bank, and about 4 or 5°F than that of the muck up to June. From October on all the different locations had practically the same magnitude of temperature. As a rule, the greatest amplitude occurred in the south and north slope and high point, and the smallest in the river bank and low land or muck.

The daily records show that the temperature of the south slope would begin to rise earlier and faster in the morning during the spring months than that of the north. The reason for this is obvious.

The marked influence of the slant of the surface with respect to the position of the sun on the soil temperature is even manifested on a cultivated soil with a very rough and uneven surface. Observations made upon this point have yielded some exceedingly interesting and surprising results. Thus, for instance, it was found that that side of the lumps which faced the sun in the morning would possess as much as 5°F higher temperature than that side which was shaded. Even greater differences than these were obtained between the shaded and unshaded sides of a dead furrow. If the soil was sandy, the side facing the sun would thaw almost completely and its temperature would rise several degrees above the freezing point before the opposite side began to thaw.

EFFECT OF UNDERHEATING ON THE SOIL TEMPERATURE DURING THE WINTER.

It is a very general observation that the surface of a soil which is traversed underneath by a steam heat pipe is kept free from snow during the winter, and in the spring its vegetation commences to grow much earlier than that of the adjacent soil only a short distance away. The logical inference of these observations is that heat escapes from the steam heat pipe which keeps the surrounding soil warm.

In the winter of 1915 it was decided to undertake a series of observations to determine (1) to what extent the heat lost from a steam heat pipe, in the College Campus, keeps the soil immediately above warm, and (2) how far distant from the pipe the influence of the heat escaping will be felt. To obtain this information soil mercury thermometers were placed 3 inches deep, immediately over the pipe and at various distances apart, up to 10 feet, and temperature observations were made three tims a day throughout the winter. The pipe ran from one building into another and was very long, buried a little over a foot into the ground, and was very well insulated by asbestos, cement, etc. The data obtained from December up to and including April are presented in Table 90.

TABLE 90.—EFFECT OF UNDERHEATING ON SOIL TEMPERATURE IN THE WINTER.

1914–1915.	December.				January.				February.			
	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
0″	52.70	51.51	1.19	52.15	60.35	57.46	2.89	58.82	68.04	63.68	4.36	65.88
2″	45.06	43.63	1.43	44.35	47.51	45.60	1.91	46.69	50.62	47.57	3.05	49.20
4″	38.01	36.90	1.11	37.41	38.17	37.05	1.12	37.68	40.05	37.88	2.17	39.04
5″	35.60	34.79	0.81	35.13	35.64	34.75	0.89	35.20	36.78	35.35	1.43	36.04
6″	34.08	33.22	0.86	33.62	33.54	32.86	0.68	33,20	34.83	33.67	1.16	34.23
7″	33.43	32.63	0.80	33.03	32.61	32.04	0.57	32.36	33.90	32.86	1.04	33.38
8″	......	......	......	......	......	......	......	......	......	......	......	......
9″	......	......	......	......	......	......	......	......	......	......	......	......

1914–15.	March.				April.			
	Max.	Min.	Diff.	Ave.	Max.	Min.	Diff.	Ave.
0″	99.02	91.90	7.12	96.02	83.87	72.96	10.91	79.65
2″	71.23	65.48	5.75	68.79	75.87	66.70	9.17	72.40
4″	52.72	46.47	6.25	50.09	67.43	59.02	8.41	64.30
5″	42.94	38.21	4.73	40.67	61.77	53.33	8.44	58.39
6″	42.83	37.62	5.21	40.55	59.24	50.68	9.56	55.59
7″	40.74	35.95	4.79	38.52	56.24	46.60	9.64	52.28
8″	39.38	35.24	4.14	37.20	55.95	45.90	10.05	51.93
9″	38.15	34.17	3.98	36.14	55.45	45.33	10.12	51.39

The winter of 1915 was very cold, but in spite of that the heat escaped from the steam heat pipe kept the temperature of the soil immediately above very high, from 50 to 65°F, and even prevented the soil 7 feet away from freezing. Indeed, even at a distnce of 10 feet the soil temperature was perceptibly influenced. Since the heat traveled in both opposite directions, then a lateral path of 20 feet was kept warm, but the degree of warmth, of course, decreased inversely with the distance.

As already stated, these temperature records were taken at 3-inch depth. At a lower depth, the magnitude of temperature would be greater at the respective distances.

It will be readily realized that the foregoing data are of considerable practical importance.

CONCLUSIONS.

The soil temperature has been studied at this Station for four years. The results of the investigation for the first year have already been published in a previous report. In the present report there are presented the data obtained in the following three years and the general conclusion that might be deducted from the entire investigation.

The number of factors influencing the temperature of soil is very great. These factors may be divided into two main groups, (1) the intrinsic, and (2) the external. The intrinsic factors are those contained by the soil and include the specific heat, heat conductivity, radiation, water content, evaporation of water, concentration of soil solution, topographic position, condition of surface, etc. The external factors comprise the metereological elements and include the air temperature, sunshine, wind velocity, barometric pressure, rainfall, etc. The temperature of soil, therefore, is controlled by and is the resultant of these intrinsic and external factors. Part of these factors of both groups favor a high soil temperature and part a low, and whichever class predominates determines the degree of soil temperature at any time.

The intrinsic factors play a passive and the external an active role. In other words the intrinsic factors tend to remain passive but are acted upon by the external factors. Hence, the degree of soil temperature is almost wholly controlled by the external factors and especially the air temperature, but modified by the intrinsic factors. Inequality in temperature, therefore, in the different kinds of soil during the same day will depend upon the intrinsic factors but variation in temperature in any soil in succeeding days or seasons will depend upon the external factors.

All soils possess practically the same intrinsic factors but in different degree. Witness, for example, the great disproportionality between sand and peat. Indeed these soils possess most of the intrinsic factors in opposite degree. Thus for example, peat has black color, low heat conductivity, a high water-holding capacity, etc. These same properties exist in sand in almost exactly the opposite degree. Hence a law of compensation intervenes.

This unparallelism of the various intrinsic factors in the different kinds of soil tends to give the latter an equal degree of average temperature. In other words each type of soil possesses the various intrinsic factors in a compensating or neutralizing degree and consequently they all tend to have the same average temperature under the same meteorological elements.

In excessive degree, however, certain of the intrinsic factors predominate and cause a variation in the temperature of the diverse classes of soil. The factors which are almost always responsible for differences in temperature that may exist in the different kinds of soil are the following: (1) latent heat of fusion of ice, (2) latent heat of evaporation of water, (3) a covering of the surface soil, (4) color, and (5) topographic position. All these factors are able to exert either an ephemeral or lasting predominant effect upon the temperature of the soil which possesses them.

The line of thought thus far developed is supported by the results obtained from the various experiments conducted under natural conditions.

The field studies on the temperature of different types of soil, namely, gravel, sand, humus loam, clay, and peat at 6, 12 and 18-inch depths, showed that when the surface of all these soils was covered with a thin layer of sand they had almost exactly the same average temperature throughout the year except during a short period in the spring when thawing was taking place.

Thawing would usually commence about the end of March or beginning of April. The sand and gravel would thaw completely first, followed by clay and loam, one or two days later, and peat ten or fifteen days later. Immediately upon complete thawing the average temperature of the mineral soils would rise rapidly and approach the same magnitude in about three or four days. Meantime the average temperature of the peat would be far below, on account of the slow rate of thawing. As soon, however, as it was also completely thawed its temperature would rise very rapidly and would approach, in a few days, that of the mineral soils. The average temperature then of all the soils would be remarkably the same from this period on throughout the summer, fall and winter months until the next thawing period.

During the summer months the peat would have a monthly average temperature of a few tenths of a degree higher than the mineral soils. In the fall, however, the sand and gravel would possess a slightly higher monthly average temperature than the peat.

Whenever rapid and sudden changes of air temperature occurred the sand and gravel would warm and cool the fastest, followed by clay, loam and peat, respectively. The equilibrium or equality, however, would quickly be reestablished.

The degree of amplitude was greatest in sand and gravel, somewhat smaller in loam and clay, and least in peat. The highest fluctuation occurred in summer and the lowest in winter.

The maximum temperature was approximately the same for all types of soil, after complete thawing had taken place, but the minimum varied somewhat; it was lowest in sand and gravel, slightly higher in clay and loam, and highest in peat. Even during the winter, the minimum varied only slightly in the different soils. During a sudden severe cold weather, however, the minimum of the sand and gravel would fall appreciably lower than that of the peat, but the differences would not be very great.

The equality of average temperature in the diverse classes of soil, therefore, was not made up of extreme variation in the maximum and minimum temperature between them, i. e., a very high maximum and low minimum in one soil and a low maximum and high minimum in another.

The uniformity of average temperature throughout the year except during the short period in the spring when thawing was taking place, of the different types of soil when their surface was covered with a thin layer of sand, is really remarkable. It shows that there was only one intrinsic factor, the heat of fusion of ice, which predominated and caused a variation in their average temperature and especially between sand or gravel and peat. All the other intrinsic factors existed in such a compensating degree and order in these different kinds of soil that they caused and maintained in them an equal magnitude of temperature, after complete thawing took place.

When these same types of soil, however, were not covered with a thin layer of sand but their natural surface was allowed to be exposed to the atmosphere somewhat different results were obtained. Their average temperature, instead of being equal throughout the year except during the process of thawing, was about the same only during the fall and winter months, but varied somewhat during the spring and summer months. During the latter seasons the sand and gravel would have the highest average temperature, the clay and loam slightly lower, and peat the lowest. The difference, however, between the mineral soils was comparativly small, but the variation between the sand or gravel and peat was quite appreciable, especially in the early spring when thawing was taking place. By the commencement of fall, however, these differences would disappear and all the soils then would have the same magnitude of average temperature, and would continue to be equally warm until the next thawing period, in almost exactly the same way as when they were covered with the thin layer of sand. In the spring the peat would not thaw and its temperature would not approach that of the mineral soils after complete thawing, as rapidly as when its surface was covered with the thin layer of sand.

Besides the average temperature the order of the maximum and minimum temperature also differed in the various types of soil under the two surface conditions. As previously stated when the surface of these soils was covered with a thin layer of sand their maximum temperature was approximately the same in all of them, but the minimum varied somewhat; the sand and gravel would usually be the coldest in the morning followed by clay, loam and peat, respectively. But when their surfect was not covered, this order of the maximum and minimum temperature was just reversed.

The inequality in average temperature during the spring months, after complete thawing had taken place, and also during the summer months, of the different types of soil when their natural surface was allowed to be exposed to the atmosphere, indicates that there was one intrinsic factor, the heat of evaporation of water, which predominated and caused the variation. The clay and loam, and especially the peat having a greater percentage of water than the sand and gravel, lost more water by evaporation than the latter and consequently their average temperature was kept correspondingly lower. When the surface of all the soils, however, was covered with the thin layer of sand, the excessive evaporation of the clay, loam and peat was reduced and consequently their average temperature was raised to the same magnitude as that of the sand and gravel.

There are good reasons to believe, that a cover of growing vegetation would cause identical equality of average temperature in the diverse types of soil as the cover of sand. Hence, variations in temperature that are observed in these soils in bare condition, may not exist when they are under crops, i. e., after complete thawing has taken place.

The remarkably even magnitude of average temperature of the different types of soil, both when their surface was covered and uncovered, in the fall and winter months, is of the greatest interest. It shows that there was no one single factor during these seasons, not even the specific heat of water, which had a predominant and controlling influence in causing these various soils to cool differently and be unequally warm.

The rapidity with which the clay and loam thawed and the rise of their temperature to the same degree as that of sand and gravel in such a short time, both when their surface was covered and not covered with sand, contradicts the exaggerated general belief that these soils possess a greatly lower temperature during the spring and therefore should be classed as cold soils. This last term, however, may be justly applied to peat, especially when it is not covered with sand.

There was some heat coming to the surface during the winter from the lower and warmer depths which tended to keep the temperature of the upper depths higher, and aided in the thawing and raising the temperature in the spring. The average air temperature was lower than that of any soil at the 2, 4, 6, 12 and 18-inch depths, throughout the year. The amplitude of the air temperature, however, was far greater than that of all the soils at any of the above depths, also throughout the year.

The maximum temperature of all the soils at one quarter of an inch depth was about 30°F higher during hot and clear days than that of the air at an elevation of four feet.

The minimum temperature of all the soils except peat, however, immediately at the surface was only about 1 or 2°F higher, as a monthly average, than that of the air at a height of four feet. That of the peat was slightly lower than that of the air.

Unless the various soils were frozen they always had a gradient of temperature at their adjacent depths. This gradient of temperature, however, reversed itself between day and night during the warm part of the year to the depth that the diurnal-nocturnal amplitude of oscillation of temperature extended. During the day it decreased from the surface downward and during the night the reverse was true. There were two periods, one in the morning and one in the evening, when the reversion took place, that this gradient was not regular. During the day, at the time that the maximum temperature was attained at the surface, this gradient was very large at the adjacent dephts, the difference between the surface and the 6-in. depth being sometimes as high as 30° F, but during the night at the time when the minimum was reached at the surface, it was comparatively small, the greatest differences between the same depths being only about 10°F.

The soils, down to the depth that the diurnal-nocturnal amplitude of oscillation of temperature extended, received their temperature in the form of waves. There were, of course, two types of waves, a warm and a cold. Both of these classes of waves penetrated the soils in gradual increase of intensities of temperature.

The rate at which the maximum and minimum temperature waves traveled through any particular soil tended to follow approximately a mathematical law. This law may be stated thus: The lag of the maximum and minimum epochs tended to be approximately proportional to the depth, in all the different types of soil.

The decrease of the diurnal-nocturnal amplitude of temperature with the increase in depth also followed a mathematical law in all the diverse types of soil and indeed the geometric progression law. This law may be stated as follows: The diurnal-nocturnal amplitude of oscillation of temperature decreased in geometric progression as the depth increased in arithmetic progression, in all the different types of soil.

The four years' data obtained on the temperature of sand to which was added different percentages of organic matter (peat) showed that during the fall and winter months all these soils had approximately the same degree of average temperature but in the spring and summer months it varied somewhat. During the latter months the sand which received no organic matter and had a white-colored surface and the peat had about the same and lower average temperature than the other soils which were treated with various percentages of peat.

In the spring all the treated and untreated mineral soils would thaw first and approximately at the same time, the peat, however, would thaw last and several days later.

The amplitude of temperature at the 3 and 5-inch depths was high but approximately of equal degree in all the treated and untreated soils, but comparatively low in the peat.

The higher average temperature of the sand to which was added various quantities of peat during the spring months after thawing, and in the summer months, over the sand which received no peat and had white-colored surface, and the peat, goes to prove that the white color reflected so much of the solar energy that it kept the temperature of white sand low in spite of the many other intrinsic factors which are favorable for a high temperature. On the other hand a large amount of evaporation of water predominated over the high heat absorptive power of the black color and consequently kept the temperature of the peat also low. Soils, however, possessing these properties in medium degree maintained a higher average temperature during the same periods.

The general belief that there exists a large difference in temperature between a cultivated and uncultivated soil is much exaggerated. The observations conducted for four years show that the uncultivated soil had practically the same or only a few tenths of a degree higher temperature during the spring months than the cultivated, and only about 1°F higher during the summer months. During the fall and winter months there was hardly any difference.

There did exist, however, a very marked difference in average temperature between thse two bare soils and one covered with growing vegetation. The data show that immediately upon the commencement of growth of the vegetation the temperature of the sod or grass land would become decidedly lower than that of the cultivated and uncultivated soil. The maximum difference would be reached in June and July when the sod soil at the 7-inch depth for instance would be about 6°F colder than the bare soils. This difference, however, would become smaller and smaller so that by September it would entirely disappear and by October the order would be reversed; the bare plots would become colder and the sod warmer. The latter would continue to have a higher temperature throughout the fall and winter months.

A cover of vegetation, therefore, had a very large controlling influence upon the soil temperature; during the warmest part of the year it kept the soil cold and during the coldest part, warm. Indeed, a cover of vegetation is one of the most efficient and expedient means of protecting the soil against extreme low temperature during the winter.

Like the vegetation cover, a thick layer of snow is also a most efficient agent for keeping the soil warm in the winter and preventing it from attaining extreme low temperature during severe cold weather. Observations made for four years upon this subject showed that in exceptional cold weather the soil covered with a vegetation cover and a layer of snow would have 25°F higher temperature than a bare soil at 3-inch depth.

Certain topographic positions have a marked controlling influence upon the soil temperature. A southern exposure had about 2°F higher average temperature than a northern during the spring and summer months, but during the fall and winter months both locations would be equally warm. The soil temperature at a river bank was far below that of the south and north slope during the spring and summer months but slighthly higher during the fall and winter months.

The marked influence of the slant of the surface with respect to the position of the sun on the soil temperature is even manifested on a cultivated soil with very lumpy and uneven surface. The sides of the lumps or dead furrows facing the sun in the morning had a higher temperature than those shaded.

The heat escaping from a well-insulated steam pipe buried about a foot into the ground influenced the temperature of the surrounding soil to a considerable extent. The temperature of the soil was highest immediately above the pipe and diminished with increase in distance. The influence was felt and the soil was prevented from freezing to a distance of about 10 feet on each side, making a total lateral distance of about 20 feet.

Speaking broadly, the ability of man to control or influence the soil temperature under field conditions, one way or the other, is greatly limited. Since the temperature of the soil is finally dependent upon the meteorological elements and especially upon the air temperature, which are beyond his control, all he can do is to vary some of the intrinsic factors and thereby modify somewhat the degree of soil temperature, either temporarily or permanently. The factors which are in his power to modify in order to hasten the rise of temperature in the spring, which is the most important time, are: (1) draining the soil from an excess of water, (2) creating a dark color at the surface, (3) covering the surface of these soils prone to low temperature with a thin layer of sand, and (4) compacting the surface of the cultivated soil.

A fulfillment of the above factors except (1) would probably be of some benefit only if the planting is to be done in the spring. If it is already accomplished in the fall so that the plants have already begun to shade the ground then the creation of conditions (2), (3), and (4) would be of practically no important benefit.

Furthermore, by creating conditions (2), (3), and (4) the temperature of the heavy types of the mineral soils could hardly be increased more than 2°F; that of the peat, however, could be raised almost twice this amount. The practical importance of this comparatively small increase in average temperature, therefore, would depend upon the sensitiveness of the germinating seed and growing plant upon the temperature and upon the time of the growing season.

Again, it must be remembered, that it is not only the soil temperature that influences the growth of plants, but the air temperature as well. Hence, if the air temperature is the same over a certain area then the influence of small variation of temperature that may exist in adjacent different types of soil would be of lesser significance.

Some of the intrinsic factors which man can modify to keep the soil warm or protect it from extreme low temperature in the winter are: (1) covering the soil with straw or any other material, and (2) heating the soil.

Man can regulate the soil temperature far easier, more successfully and probably with far greater practical results during the cold part of the year than at any other other time.

THE FREEZING POINT METHOD AS A NEW MEANS OF DETERMINING THE NATURE OF ACIDITY AND LIME REQUIREMENTS OF SOILS.

Technical Bulletin No. 27.

INTRODUCTION.

Perhaps no other single subject in soils is receiving at present more attention and investigation than that of soil acidity. Again, probably no other soil problem is so rich in laboratory methods[1] as the acidity of soils. Both of these facts unmistakably go to indicate that the subject *per se* is of urgent importance and that probably none of the present methods is proving entirely satisfactory for its solution.

That the subjct is of great and urgent practical importance can scarcely be questioned. It appears now to be an established fact that the so-called acidity of soils is proving to be a limiting factor in crop growth, at least for many agricultural plants, and that the infertility of many soils, in part or in whole, may be safely attributed directly or indirectly, to this factor. The necessity, therefore, of correcting this acid condition of soils and thereby rendering them more efficient and productive, is of paramount importance.

Experience has shown that when the acid soils are treated with lime in its various forms the growth of some crops is greatly increased, while that of others, very little if any. This has led to the logical conclusion that the acid condition of soils affects the various plants differently.

Since this is true, then it would appear that probably no soil acidity laboratory method could ever be expected to tell exactly to what extent the soil acidity should be corrected by the application of lime. This point would have to be settled by field experiments.

Most that a soil acidity laboratory method might ever be expected to do from the practical standpoint, is to show the maximum lime requirement of soils and then apply the lime according to the crops planted. Any soil acidity laboratory method, therefore, that would be able to indicate definitely and correctly the maximum lime requirement of soils, would be of the greatest value.

It appears very doubtful if any of the present soil acidity methods gives the true lime requirement of soils. Thus, take the Veitch method which is quite generally considered to be probably the most satisfactory from the practical standpoint, i. e., it comes closer in indicating the true lime requirement of soils than any other method, although many of the other methods show almost identical results. A critical consideration of the nature of the soil mass and the kind of indicator employed seems to point very strongly to the fact that this method probably does not indicate the total maximum lime requirement of soils. A consideration of the soil mass shows that it is composed mainly of silicates of the

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(1) It is not deemed necessary to review the numerous soil acidity methods that have been proposed, since several of the recent articles on soil acidity contain quite complete reviews of these different methods. Perhaps the most complete resume of all the various soil acidity methods is contained in a recent bulletin written by Dr. W. Frear entitled: Sour soils and Liming. Bulletin 261, Dept. of Agr., Commonwealth of Pennsylvania.

metals aluminum, iron, calcium, potassium, sodium, and magnesium. These silicates are salts of strong bases with weak acids, and being somewhat soluble in water are greatly hydrolyzed. Upon hydrolysis the acid remains more or less in an insoluble form while the bases go readily into solution. Now it is a well known fact that the strength of the bases and acids has a very marked effect upon the indicators commonly employed for determining the end point of neutralization. Thus, for example, phenolphthalein cannot be used with weak acids or weak bases. If the acid is so weak that its salts, even with strong bases, are hydrolyzed, the free base begins to react with phenolphthalein long before enough base has been added to completely neutralize the acid. The result is the appearance of a faint color on the addition of a little alkali. In the Veitch method phenolphthalein is employed as the indicator. Now it is readily evident that if the soil contains soluble weak acids consisting of silicic and organic acids, the alkali color begins to manifest itself long before enough of the base is added to completely neutralize all the soluble weak acids present. The result is that the soil shows a low lime requirement and consequently its true maximum lime requirement will not be known.

As it will be subsequently shown, however, *the acidity of the mineral soils appears to be due almost entirely to the acid alumino-silicates, silicic acid, and silica, and that the mineral soils rarely if ever contain permanently free soluble acids.* Consequently the above objection to using phenolphthalein in the Veitch method is neither absolutely valid nor so serious. The aforesaid objection, however, would hold true in the hydrolysis of the minerals. As already stated these silicates or silico-minerals upon hydrolysis yield soluble bases and more or less insoluble acid. If the bases are present even in small quantities they will give a neutral or alkaline reaction both to the phenolphthalein and litmus paper, even if the silicates are far from being completely neutralized, or satisfied with a base. This is due of course to the high ionization of the bases and consequently to their strong reaction upon the indicator as compared with the almost negligible ionization of the acid and therefore its extremely weak reaction upon the same indicators. It is very possible to have a soil which would be neutral according to the Veitch method and litmus paper test and yet this soil may possess a large amount of negative or inactive acidity, as it is generally termed, i. e., the acid radical of the soil, which is composed almost entirely of alumino-silicate, silica and silicic acid, is far from being entirely satisfied with bases.

A simple experiment, which apparently would seem to demonstrate the validity of the above statements and at the same time help to make the point in question more clear, may be cited as follows: If to 1 gram of pure silicic acid is added 10 c. c. of distilled water and the mixture stirred and a blue litmus paper is placed into it, the color of the litmus paper will shortly turn decidedly red. If now to this mixture is added a few drops of N/25 $Ca(OH)_2$ the red will shortly turn faint blue or neutral and continue to remain faint blue or neutral. Yet this one gram of silicic acid requires nearly 80 c. c. N/25 $Ca(OH)_2$ to be fully satisfied before the $Ca(OH)_2$ can remain in solution to affect the concentration of the liquid phase, and therefore, also the freezing point depression. In other words, the $Ca(OH)_2$ added to the silicic acid immediately combines with it to form calcium silicate and thereby is removed from the liquid phase. The $Ca(OH)_2$ which is in solution is that only which is due to hydrolysis of the calcium silicate compound. When the silicic acid, however, is fully saturated or satisfied with the $Ca(OH)_2$ then the hydrate will remain in the solution and affect the freezing point depression. In spite of this tremendous amount of lime absorption or requirement by the silicic acid, a neutral reaction is attained, according to the phenolphthalein and litmus paper indicators, when only about one-hundredth of the amount required is added.

That the hydrolisis of the soil minerals and the effect of the resulting products upon the phenolphthalein indicator play a large role in the estimation of the lime requirement of soils by the Veitch method seems to have been recognized by Veitch himself, although he does not appear to have attached any serious consequences to the matter. Veitch found that the length of time the treated soil was allowed to stand had considerable effect upon the lime requirements.[2] When the solution was allowed to go on from 48 to 72 hours the pink color with phenolphthalein was developed with less added lime water than when the solution was allowed to stand 16 hours or less. Furtheromer, Veitch found that some soils which were acid when allowed to stand 16 hours gave an alkaline filtrate when permitted to stand 24 to 48 hours longer.

Any one who has tried to test soil acidity with the litmus paper test will doubtless have noticed that many soils, even those which show lime requirement by the Veitch method, will turn the red litmus pink or neutral on long standing, especially when the soil is treated with an excess of water. This phenomenon can safely be attributed to hydrolysis.

Veitch's method calls for treating the soil with water and $Ca(OH)_2$ and then drying down at once on a steam bath. Now it is a well known fact that hydrolysis is appreciably increased by a rise in temperature.

Even practical experience seems to indicate that the Veitch method may not be showing the true maximum lime requirement of soils, and consequently the proper amount of lime may not be applied to the soils for the successful growth of crops. Thus, for instance, in a recent paper by Ames and Schollenberger of the Ohio Experiment Station[3], it is shown that the soil of some of the experimental plots, which was limed a long time ago, is now almost neutral or alkaline according to the Veitch method, yet the growth of clover will be materially benefited by an application of lime. In speaking of the possible usefulness of the various methods for comparative purposes when different soil treatments have been made, Ames and Schollenger make the following statement: "If either the Hopkins or the Veitch test were used to obtain a figure for the limed soil's requirement, the results would lead to erroneous conclusions, because the Veitch method indicates that the limed halves of all the plots are alkaline. . . ." Yet an application of lime to these plots will materially benefit the growth of clover.

The behavior of the Veitch method towards this soil which was limed a long time ago but with amounts which were evidently too small, since the growth of clover will be enhanced with further applications, is in perfect agreement with the theory of hydrolysis and the reactivity of the hydrolyzed products upon the phenolphthalein indicator, as already set forth.

Thus far an attempt has been made to show that probably none of the

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(2) Jour. Am. Chem. Soc. 24 (1904), 637.
(3) Jour. Ind. Eng. Chem. 8 (1916), 243.

methods now in vogue are capable of indicating the total maximum lime requirement of soils. The Veitch method has been mainly taken into the discussion because it is generally considered to be the standard method. The other methods are based upon different principles and although the individual criticisms would accordingly vary, yet the main and important criticism, namely that they may not indicate the total maximum lime requirement of the soils, is the same. It will have been noticed that nothing has been said concerning the empirical nature of these methods, the comparatively slight variations in methods of procedure affect the result obtained markedly. The errors arising from this source, however, serious as they may be, are insignificant in comparison with the above main objection.

It is hoped that the foregoing critique will not be considered as a condemnation of any of the soil acidity methods, and especially of the Veitch method! Indeed that is far from being the intention and desire of the writer. He fully realizes and acknowledges their usefulness. In offering these criticisms it is done with the firm belief that they are based upon fundamental principles and experimental data; and incidentally to emphasize the need of some new method which will indicate definitely and accurately the true lime requirement of soils.

In employing the freezing point method to measure the concentration of the soil solution directly in the soil; the effect of the application of fertilizers upon the concentration of the soil solution[4]; the concentration of the cell sap directly in the plant tissue[5]; and the effects of biological activities directly in the soil[6], the idea occurred that the freezing point method might also be employed to determine or study both the nature of soil acidity and the lime requirement of soils. It was reasoned that if the soil contains a free soluble acid, this acid would possess a definite freezing point depression at a certain concentration. Upon titrating this acid with a base, such as $Ca(OH)_2$, a salt would be formed. This salt would probably possess a different freezing point depression from that of either of the reacting agents. The depression then should vary as more and more of the lime is added to the soil until the neutralization point is reached where the formation of the salt is completed and then the direction of the depression should change. If on the other hand, the soil does not contain a free soluble acid but possesses an absorptive power for lime, due to its unsaturated or unsatisfied silicate compounds and organic matter, then the depression of the freezing point of the soil should remain the same as more and more lime is added until these silicate compounds and organic matter are satisfied with the base, and then it should increase with further addition of $Ca(OH)_2$. Finally, if the soil is alkaline or already saturated with bases, then the depression should begin to rise immediately upon adding a small amount of $Ca(OH)_2$ to the soil.

Happily all these *a priori* predictions were actually and experimentally realized in soils exactly as they are described above.

The freezing point method then promises of being capable to perform three functions simultaneously: (1) to indicate whether or not a soil needs lime, (2) the quantity it requires, and (3) the nature of its acidity.

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(4) Tech. Bul. 24, 1915, Mich. Expt. Sta.
(5) J. Am. Soc. Agr. 8, 1916.
(6) Science, 44, 65, 1916.

Using the Veitch method as a standard for comparison, the freezing point method shows that the soils and especially the loams, clays and mucks or peats, require far greater amounts of lime to satisfy completely their unsaturated compounds than the former method does. It appears that this maximum requirement as obtained by the freezing point method represents the true lime requirement of soils. *By true lime requirement is meant the total maximum amount of lime required by the soils to neutralize any of their soluble acid or acid salts, and to satisfy their absorption-adsorption phenomena for* $Ca(OH)_2$.

While the freezing point method probably indicates the true lime requirement of soils, no claim is made that it is necessary to add all that amount of lime to the soils; this point will ultimately have to be decided in the field, using the plant as the indicator. As previously intimated, probably no laboratory method, including the freezing point method, could ever be expected to designate definitely how much lime should be added to the soil. This is clearly obvious from the fact that the plant is used as an indicator to determine the effects of acidity and basicity upon its growth, and since it is found that different plants are affected differently by these qualities. All that a laboratory method might ever be expected to do, at least from the practical standpoint, is to show the maximum lime requirement of the soils and then apply the lime to these soils according to the requirement of the crops planted. This certainly appears to be the most rational and intelligent procedure. However, the experience of various observers goes to indicate very strongly that heavy applications of lime increase the growth of most crops very markedly, and these quantities are in accordance with those indicated by the freezing point method.

In the present bulletin, therefore, there is presented the freezing point method as a new method for determining the lime requirement of soils and possibly the nature of their acidity; also the principles and description of the method; and some of the experimental data obtained.

PRINCIPLE OF THE METHOD.

As already stated the principle of the freezing point method for determining the nature of soil acidity and lime requirement is based upon the following facts: (1) That if a soil contains a soluble acid or acid salt its freezing point depression decreases more or less regularly and gradually with the increase in the amount of $Ca(OH)_2$ added until the points of neutralization and saturation are reached and then it begins to increase. (2) If on the other hand a soil contains neither a soluble acid nor an acid salt but possesses an absorptive power for lime, due probably to the unsatisfied silicate compounds and organic matter, the freezing point depression remains constant as more and more of $Ca(OH)_2$ is added to the soil, until the absorptive power is satisfied and then the freezing point depression commences to rise. (3) Finally, if the soil contains neither a free soluble acid or acid salt, nor an absorptive power for lime, i. e., it is already alkaline and satisfied, then the freezing point depression starts to ascend almost immediately upon the addition of a small amount of $Ca(OH)_2$. These principles are clearly illustrated by the following examples.

The first principle, that the freezing point depression of a soil containing a soluble acid or acid salt decreases with increased amount of $Ca(OH)_2$ added until the point of neutralization is reached and then begins to increase, was established (1) by pure acids and acid salts, and (2) with soils to which were added acids and acid salts. In Table 1 there are shown the freezing point depressions of HCl, H_2SO_4, $H_2C_2O_4$ and $Al_2(NO_3)_6$ in pure solutions titrated with $Ca(OH)_2$. These results are graphically represented in figures 1a, 1b, 1c and 1d. In order to avoid the factor of dilution of the reagents, the acids and acid salts were sufficiently diluted to make their freezing point depression much smaller than that of the $Ca(OH)_2$ whose depression was .105° C. It should be stated that the results below are presented solely to illustrate the principle and not necessarily the exact neutralization point.

TABLE 1. THE FREEZING POINT DEPRESSION OF HCl, H_2SO_4, $H_2C_2O_4$ AND $Al_2(NO_3)_6$ TO WHICH WERE ADDED DIFFERENT AMOUNTS OF $Ca(OH)_2$.

Reagents.	Depression
HCl	.055°C
plus 2 c. c. $Ca(OH)_2$	.045
plus 1 c. c. $Ca(OH)_2$	.040
plus 1 c. c. $Ca(OH)_2$	.039
plus 1 c. c. $Ca(OH)_2$	.041
plus 1 c. c. $Ca(OH)_2$	.045
$H_2C_2O_4$	.040°C
plus 3 c. c. $Ca(OH)_2$	.021
plus 2 c. c. $Ca(OH)_2$	.010
plus 2 c. c. $Ca(OH)_2$	.000
plus 1 c. c. $Ca(OH)_2$	.002
plus 5 c. c. $Ca(OH)_2$	.025
H_2SO_4	.048°C
plus 3 c. c. $Ca(OH)_2$	.030
plus 1 c. c. $Ca(OH)_2$	.029
plus 1 c. c. $Ca(OH)_2$	.031
plus 4 c. c. $Ca(OH)_2$	.046
$Al_2(NO_3)_6$	.060°C
plus 2 c. c. $Ca(OH)_2$	.057
plus 4 c. c. $Ca(OH)_2$	.050
plus 2 c. c. $Ca(OH)_2$	.051
plus 5 c. c. $Ca(OH)_2$	.061

An inspection of the foregoing results bears out perfectly what has already been said, namely, the freezing point depression of the acids and acid salts decreases as more and more $Ca(OH)_2$ is added to them until a certain point, the neutralization point, is reached and then it commences to increase with further addition of the hydrate.

Now it will be of interest to know whether the same general results are obtained when these acids and acid salts are added to the soil and the titration is done in the soil. Table 2 contains the results of a few typical experiments bearing upon this point. These results are graphically represented in figures 2a, and 2b. The experiments consisted of adding 10 c. c. of the acids or acid salts to 2 grams of soil and then following the same procedure as in the case of the pure solution.

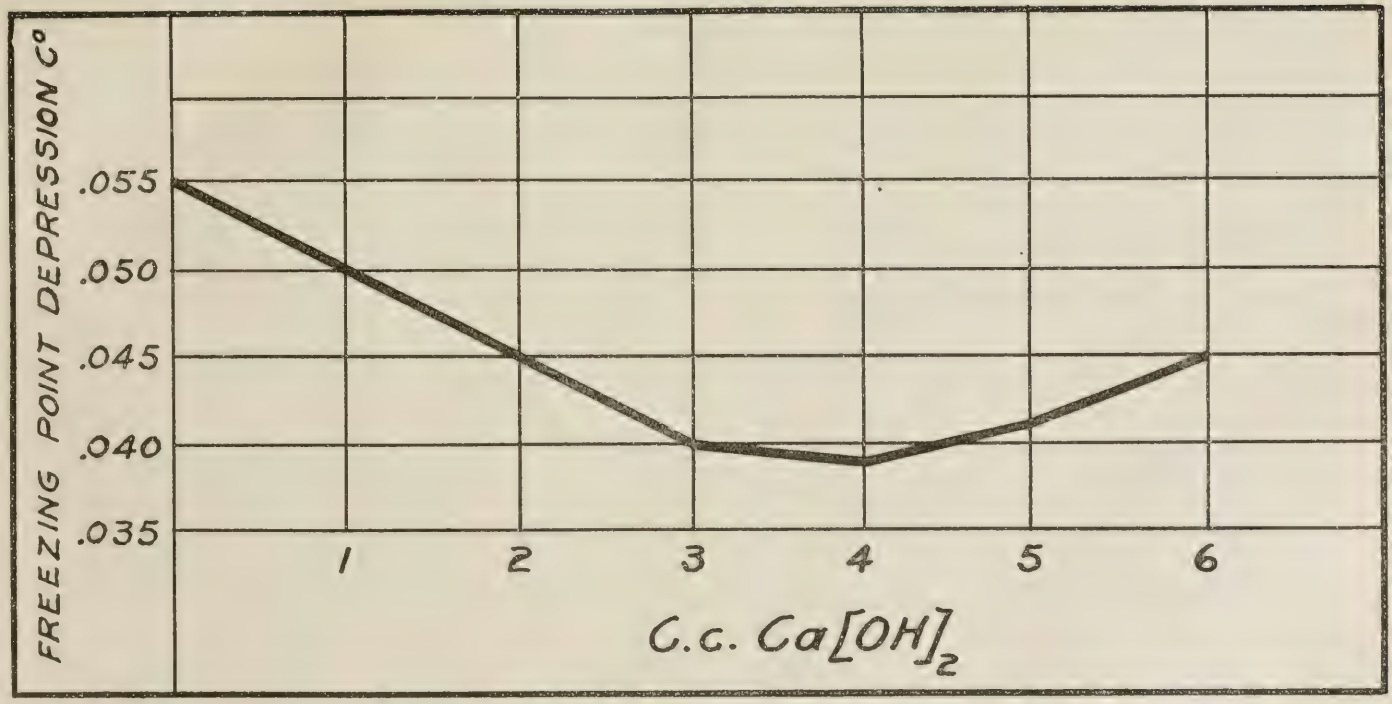

FIGURE 1a. Curve showing the decrease in the depression of HCl by the addition of $Ca(OH)_2$ down to a certain point and then the increase with further addition of $Ca(OH)_2$

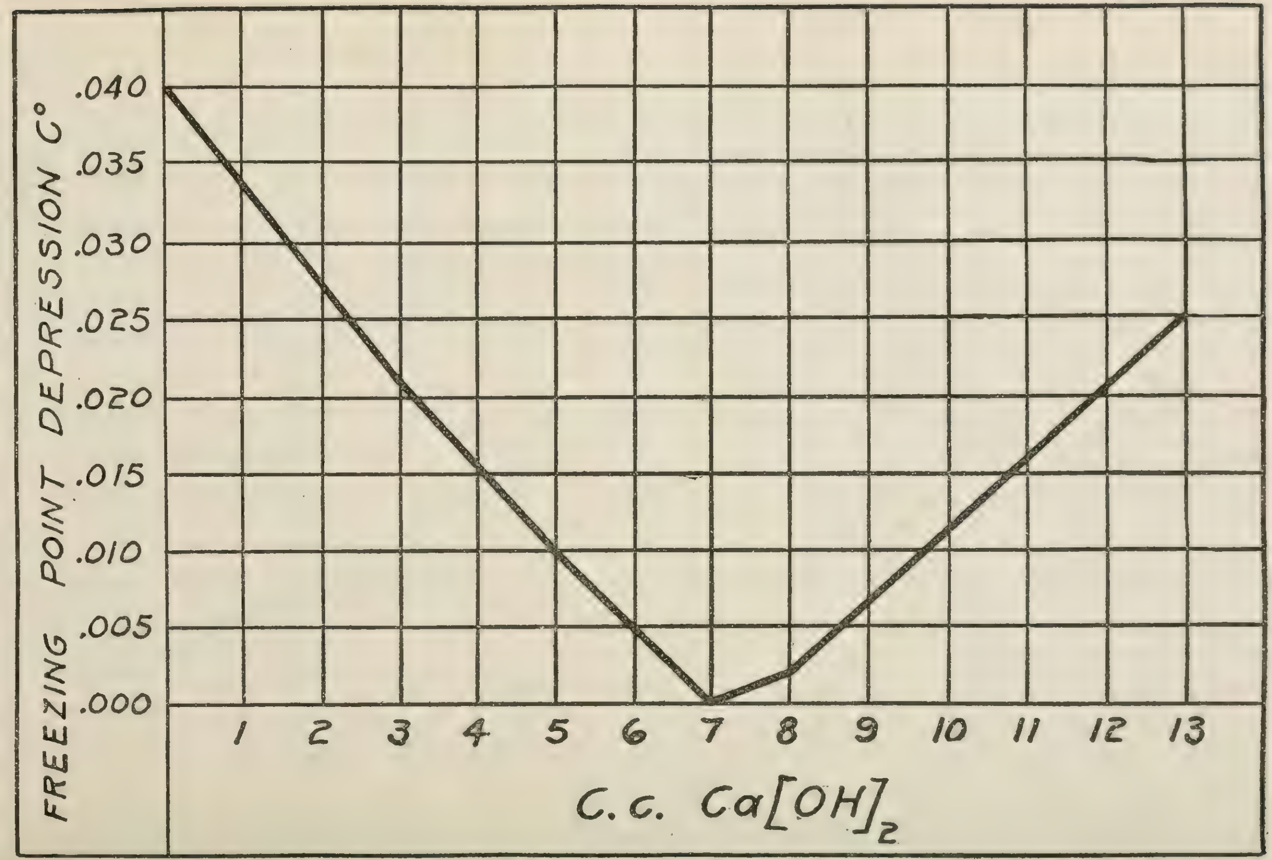

FIGURE 1b. Curve showing the decrease in the depression of $H_2C_2O_4$ with the addition of $Ca(OH)_2$ down to a certain point and then the increase with further addition of $Ca(OH)_2$

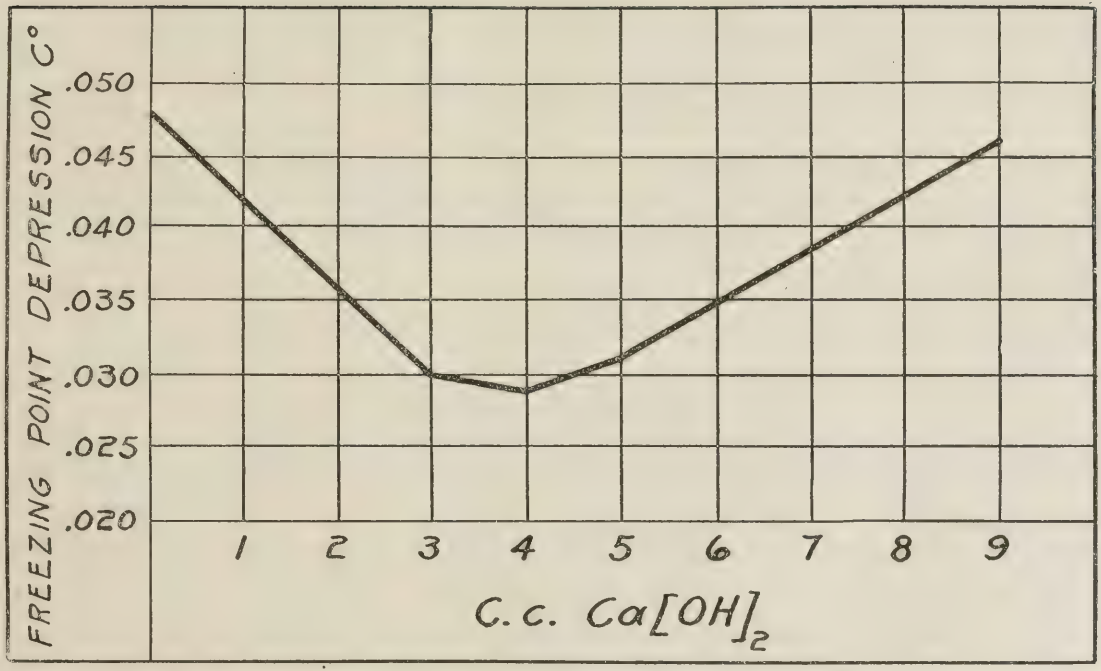

FIGURE 1c. Curve showing the decrease in the depression of H_2SO_4 by the addition of $Ca(OH)_2$ down to a certain point and then the increase with further addition of $Ca(OH)_2$

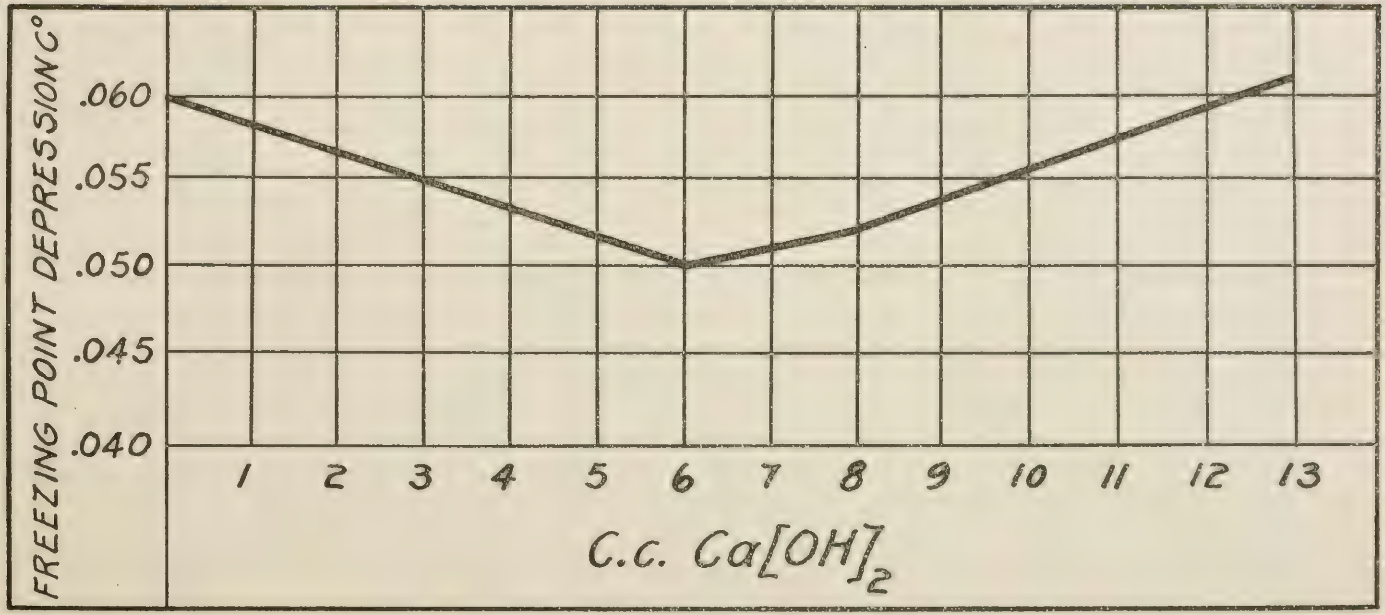

FIGURE 1d. Curve showing the decrease in the depression of $Al_2(NO_3)_6$ by the addition of $Ca(OH)_2$ down to a certain point and then the increase with further addition of $Ca(OH)_2$

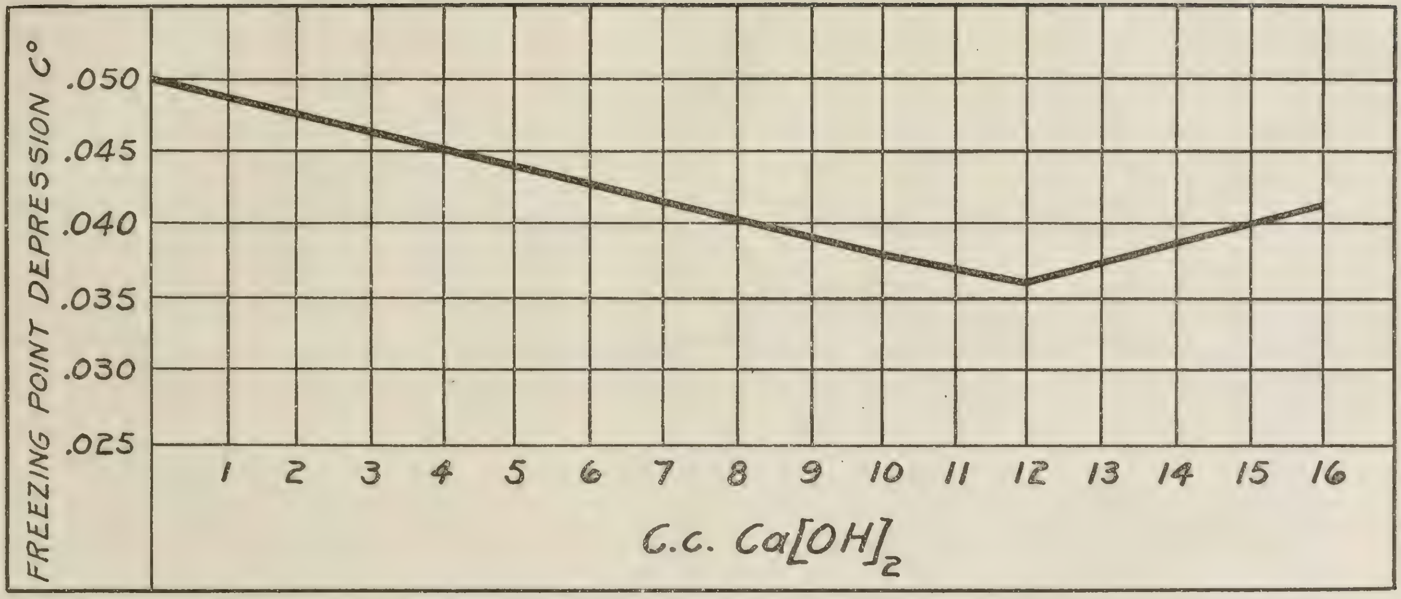

FIGURE 2a. Curve showing the decrease in the depression of soil plus HCl by the addition of $Ca(OH)_2$ down to a certain point and then the increase with further addition of $Ca(OH)_2$

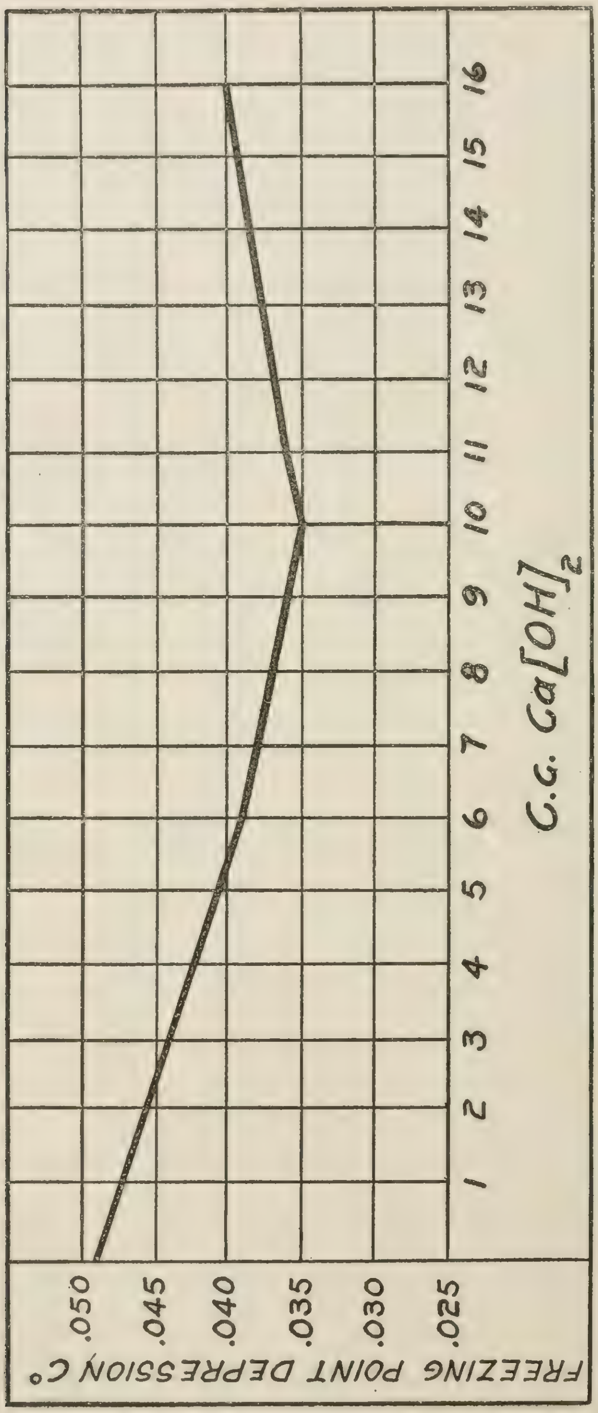

FIGURE 2b. Curve showing the decrease in the depression of soil plus $Al_2(NO_3)_6$ by the addition of $Ca(OH)_2$ down to a certain point and the increase with further addition of $Ca(OH)_2$

TABLE 2. THE FREEZING POINT DEPRESSION OF SOILS TO WHICH WERE ADDED HCl AND $Al_2(NO_3)_3$ AND TITRATED WITH $Ca(OH)_2$.

Reagents.	Depression.
Soil plus HCl	.050°C
plus 10 c. c. $Ca(OH)_2$	.038
plus 2 c. c. $Ca(OH)_2$	.036
plus 2 c. c. $Ca(OH)_2$	.039
plus 2 c. c. $Ca(OH)_2$	.041
Soil plus $Al_2(NO_3)_6$	.049°C
plus 6 c. c. $Ca(OH)_2$	.039
plus 4 c. c. $Ca(OH)_2$	.035
plus 1 c. c. $Ca(OH)_2$	.036
plus 5 c. c. $Ca(OH)_2$	.040

It will at once be seen that when a soil is treated with an acid or acid salt and then titrated with $Ca(OH)_2$ almost exactly the same general results are obtained as when the acid and acid salt are titrated alone. The main difference being that the lower part of the curves of the soils is not so sharply pointed as that of the solution. Occasionally the lower part of the curves of the soils may be slightly flattened.

The above type of curve is designated for convenience, and will be referred to throughout this paper as *an acid curve.*

The second principle, that if a soil does not contain a free acid or acid salt but possesses an absorptive power for $Ca(OH)_2$ the freezing point depression will remain the same as more and more of $Ca(OH)_2$ is added to the soil, until the absorptive power is satisfied and then it will commence to rise with further addition of $Ca(OH)_2$ was established in natural soils. The procedure consisted of adding 10 c. c. of water to 2 grams of soil and then titrating with $Ca(OH)_2$ in the same manner as above. Table 3, with its accompanying figures 3a and 3b contain the general type of results obtained.

TABLE 3. THE FREEZING POINT DEPRESSION OF SOILS TO WHICH WERE ADDED DIFFERENT AMOUNTS OF $Ca(OH)_2$.

Reagents.	Depression.
2 gm. Soil No. 1 plus 10 c. c. water	.010°C
plus 5 cc. $Ca(OH)_2$	.010
plus 3 cc. $Ca(OH)_2$	.010
plus 1 cc. $Ca(OH)_2$	.010
plus 1 cc. $Ca(OH)_2$	.012
plus 3 cc. $Ca(OH)_2$	.020
2 gm. Soil No. 2 plus 10 c. c. water	.011°C
plus 5 cc. $Ca(OH)_2$	.011
plus 1 cc. $Ca(OH)_2$	.012
plus 2 cc. $Ca(OH)_2$	.021

It becomes immediately evident that the second principle, namely that when a soil does not contain a free acid or acid salt but possesses an absorptive power for $Ca(OH)_2$ the depression remains constant as more and more of the $Ca(OH)_2$ is added until the absorptive power is satisfied, and then it begins to increase with further addition of $Ca(OH)_2$, is fully confirmed by the above data.

The curve typifying the second principle is designated for convenience, and will be referred to throughout this paper as *an absorption curve.*

If a soil possesses both an acid and an absorptive power, the curve obtained will be similar to that shown in Figure 2 which is an acid curve.

There still remains the third principle to illustrate, namely, that when a soil is alkaline or already saturated with bases, the freezing point depression will commence to rise almost immediately upon adding a small amount of $Ca(OH)_2$. A typical example of this principle is afforded in

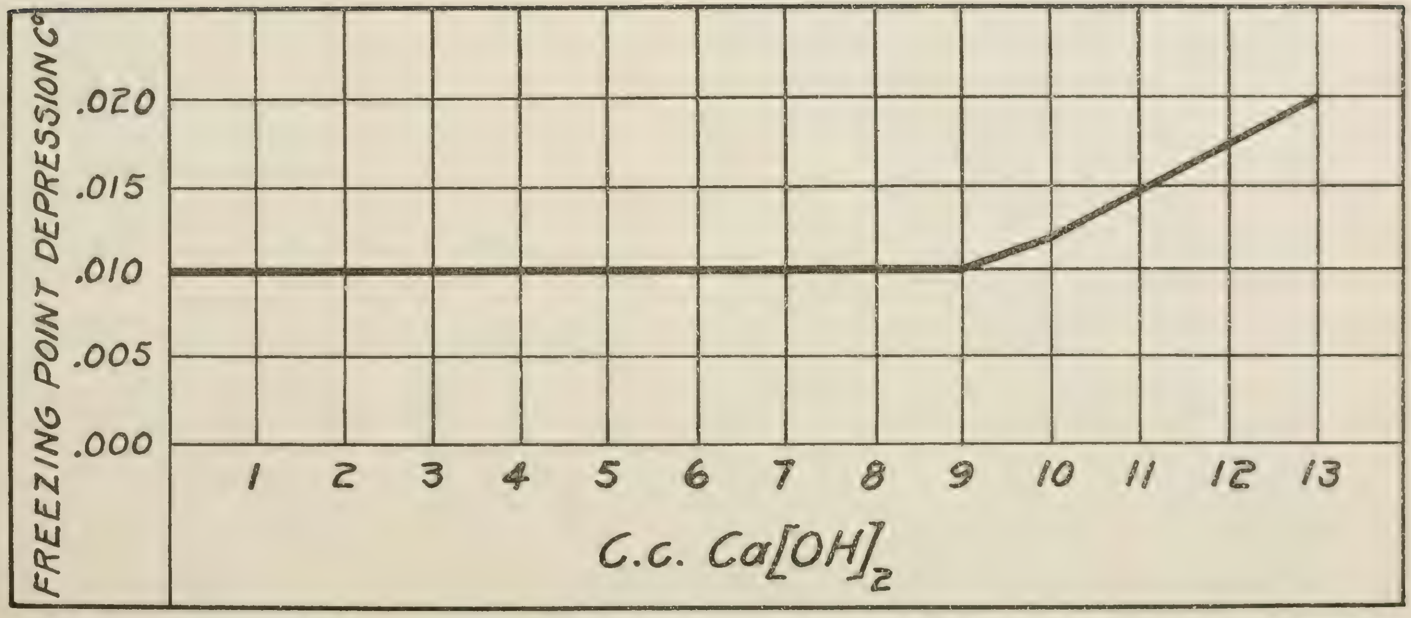

FIGURE 3a. Curve showing the constancy of the depression of soils by successive addition of $Ca(OH)_2$ up to a certain point, then the increase with further addition of $Ca(OH)_2$

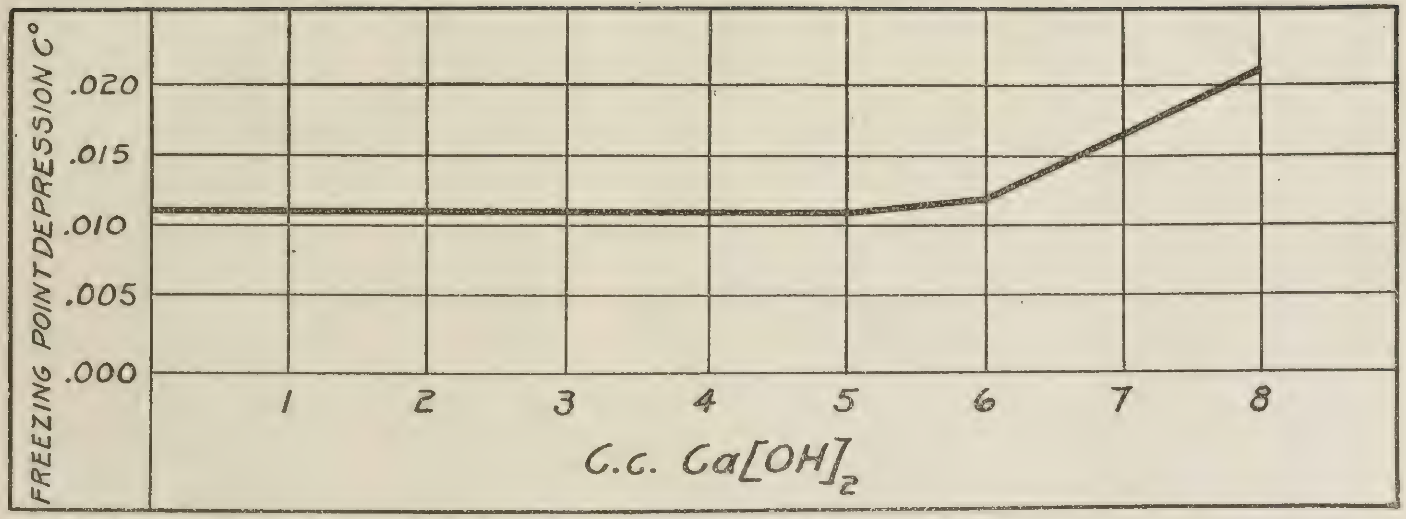

FIGURE 3b. Curve showing the constancy of the depression of soils by the successive addition of $Ca(OH)_2$ up to a certain point and then the increase with further addition

Table 4 and in the accompanying Figure 4. The numerical data were obtained by treating a soil with an excess of KOH and then titrating with $Ca(OH)_2$ in the usual manner.

TABLE 4. THE FREEZING POINT DEPRESSION OF ALKALINE SOIL TO WHICH WAS ADDED $Ca(OH)_2$.

Reagents.	Depression.
2 gm. soil plus 10 c. c. water	.015°C
plus 1 c. c. $Ca(OH)_2$	.016
plus 2 c. c. $Ca(OH)_2$	.024

The third principle, therefore, is also established by the preceding data. As will be noticed the depression commenced to rise when only 1 c. c. $Ca(OH)_2$ was added, while before this soil was saturated with KOH it required 9 c. c. of $Ca(OH)_2$ of the same strength before the freezing point depression started to rise.

The curve illustrating the third principle is named and will be referred to as the *alkaline or no-lime-requirement curve.*

Going back for a moment to the first type of curve, the acid curve, the question may be raised, may there not be other substances, besides acids and acid salts, which upon reacting with $Ca(OH)_2$, give the same type of curve? Before attempting to answer this question it is necessary first to consider the cause or causes which produce this type of curve.

According to the ionic theory, acids, bases, and salts or electrolytes, tend to break up or dissociate into ions, and the degree of dissociation varies markedly in the various electrolytes. Besides other properties, each ion causes the same amount of depression of the freezing point as a molecule. The larger the number of ions, therefore, there is present in a solution, the greater will be the freezing point depression. Since the various acids, bases, and salts, dissociate differently at the same molecular concentration their depression of the freezing point will necessarily be different.

In the light of the ionic theory, therefore, the reason for the gradual decrease in the depression of the acids and acid salts upon adding to them various amounts of $Ca(OH)_2$ until the neutralization point is reached and then commences to rise with further addition of the hydrate, becomes at once clear and self-evident. Thus, for instance, consider the case of HCl. This acid at the concentration employed possesses a definite degree of dissociation and hence also a freezing point depression. Upon the addition of a small amount of $Ca(OH)_2$ part of the acid combines with the Ca to form $CaCl_2$. The $CaCl_2$ evidently has a lower degree of dissociation than that of either HCl and $Ca(OH)_2$, and consequently the lowering of the freezing point is decreased. This decrease continues until all the acid is completely neutralized and there is present only $CaCl_2$ and H_2O. Since the degree of dissociation of CaCl is less than that of either HCl and $Ca(OH)_2$ the minimum lowering of the freezing point is registered at the point of neutralization. Upon further addition of $Ca(OH)_2$ after the neutralization is reached, the $Ca(OH)_2$ remains in solution, and since it possesses a greater degree of dissociation than the $CaCl_2$, causes an ascent in the depression.

Any salt, therefore, formed by the reaction between any acid and any base will give the same type of curve as that between HCl and $Ca(OH)_2$ provided the salt thus formed has a lower degree of dissociation than either of the acid and base. It might be stated in this connection that all the acids employed in this investigation, which included only HCl, HNO_3, H_2SO_4, and $H_2C_2O_4$, gave the usual acid curve upon being titrated with $Ca(OH)_2$, NaOH, and KOH; the NH_4OH, however, failed to give the characteristic acid curve, at least in any pronounced form.

Besides the factor of dissociation, there is still a second factor which might produce the acid curve, and that is the insolubility of the product formed from the reaction between the acid and the base. Thus, for instance, take the case of $CaH_4(PO_4)_2$ and $H_2C_2O_4$. Upon the addition of $Ca(OH)_2$ the Ca combines with $CaH_4(PO_4)_2$ and $H_2C_2O_4$ to form $Ca_3(PO_4)$ and CaC_2O_4 which are quite insoluble. As long, therefore, as the reaction is not completed the depression will diminish with the increased addition of $Ca(OH)_2$ but as soon as sufficient $Ca(OH)_2$ has been added to complete the reaction, then there will occur a minimum depression; beyond this point the depression will commence to rise with further addition of $Ca(OH)_2$.

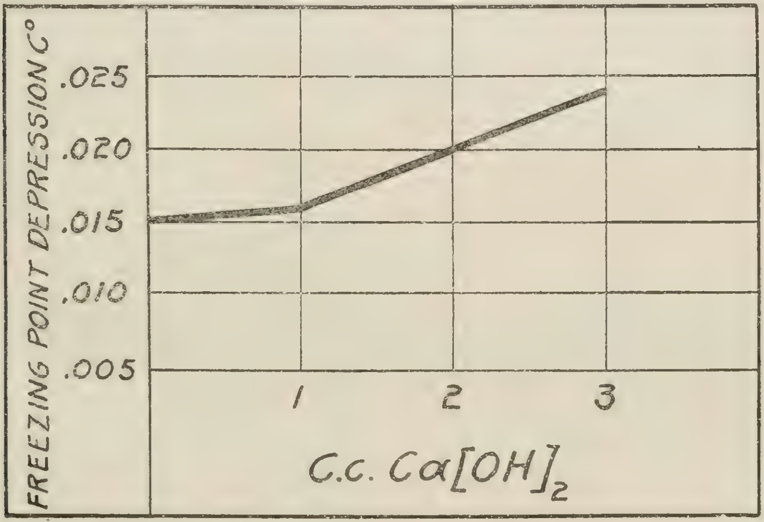

FIGURE 4. Curve showing the almost immediate rise in the depression of alkaline soils upon adding $Ca(OH)_2$

The question already raised, therefore, namely, may not substances other than acids and acid salts react with $Ca(OH)_2$ to produce a curve similar to the acid curve, can now be answered. It should be declared at once, however, that while this might be so with certain compounds, yet a large number of compounds have been employed for the purpose of testing out this point and in no case was there an acid curve obtained.

On the other hand it has been found that certain compounds which are neither acids nor bases may react between themselves to form other compounds and thus yield a curve similar to the acid curve. A most striking case of this kind may be cited the reaction between $BaCl_2$ and Ag_2SO_4. If Ag_2SO_4 is treated with $BaCl_2$ the freezing point depression decreases similarly to that when HCl is titrated with $Ca(OH)_2$ until the reaction is complete where a minimum depression is registered and then the depression commences to rise with further addition of $BaCl_2$.

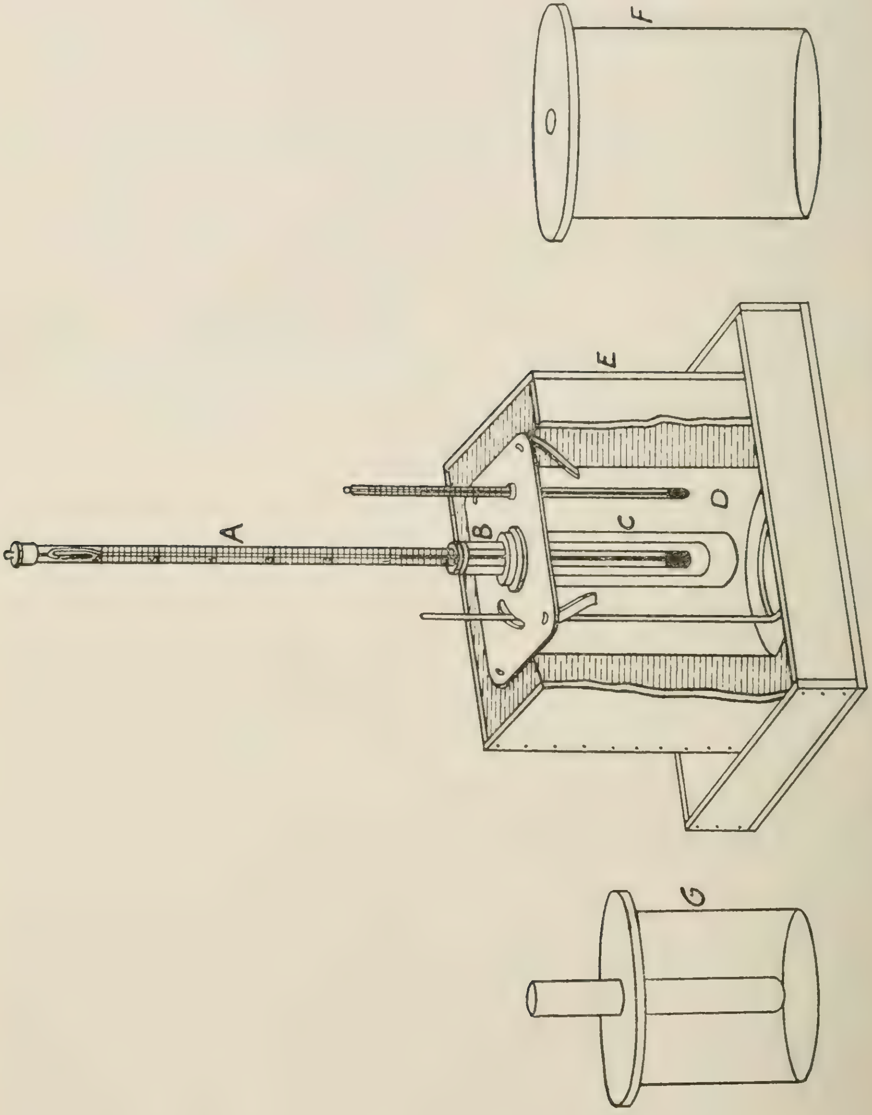

Figure 5. Apparatus for determining the lime requirement of soils.

The explanation of this penomenon is self-evident. The Ag_2SO_4 reacts with $BaCl_2$ to form $BaSO_4$ and AgCl. Both of these salts being almost insoluble cause a minimum depression when the reaction is complete. Upon further addition of $BaCl_2$ after the complete precipitation of $BaSO_4$ and AgCl, the lowering of the freezing point rises because the $BaCl_2$ remains in solution.

So while it could be stated as a very general rule that if a soil contains a free soluble acid or acid salt it will always give an acid curve when it is titrated with $Ca(OH)_2$ yet it is possible sometimes to obtain an acid curve which is not due to an acid or acid salt. Such a case, however, will probably be very rare.

In the foregoing exposition an attempt has been made to indicate briefly the underlying principles governing the freezing point method for determining the nature of acidity and lime requirement of soils. It has been seen that three distinct types of curves are obtained, and each one of these curves signifies a definite phenomenon. Next a description of the procedure involved in the method, the presentation of the detailed results obtained, and the possible explanations therefor, are in order.

DESCRIPTION OF THE METHOD AND PROCEDURE.

For determining the nature of soil acidity and lime requirement of soils by the freezing point method, the Beckmann apparatus was employed with certain modifications. The complete set of apparatus used is shown in Figure 5. It is composed of a Beckmann thermometer A, a glass tube B which contains the soil, a larger tube C which acts as an air jacket, a battery jar D which contains the cooling mixture, composed of crushed ice and NaCl, and a wooden box E in which the battery jar is placed and surrounded with poor heat conducting material to prevent rapid radiation of the cooling system. The glass tube B is 1 inch in diameter and 9 inches long, while glass tube C is 1.5 inches in diameter and 6 inches long. Vessels F and G act as accessories to the above main apparatus. Vessel F contains a cooling mixture of the same or different temperature as that in the battery jar D, and its cooling mixture serves the purpose of taking off more rapidly the initial heat of the soil mass by bringing the tube containing the soil mass into intimate contact with it. Vessel G acts simply as a stand for the thermometer when it is taken out of the glass tube B for preparing another soil sample or for adding $Ca(OH)_2$ to the soils at the end of each freezing point determination. In this vessel there is a glass tube of the same dimensions as the glass tube B. By cleaning this tube at the beginning of each experiment it becomes unnecessary to clean the bulb of the thermometer every time the latter is taken out of the soil tube to add $Ca(OH)_2$ to the soil. Near to this set of apparatus are kept burettes attached to bottles of distilled water and $Ca(OH)_2$ stock solution, or to bottles containing any other reagent employed.

For determining the lime requirement of a soil the following procedure was finally adopted: First the freezing point of pure distilled water was determined and this point was used as a standard for ascertaining the freezing point depression of soils. Then 2 grams of soil were weighed out on a chemical balance and placed into the soil tube B and added to it 10 c. c. of distilled water. The thermometer was inserted into the tube and was so arranged that the bulb was close to the bottom of the tube and entirely covered with the soil mixture. By holding the tube with one hand and the thermometer with the other the soil mixture was stirred for about a minute by gently moving the thermometer. The tube then was placed directly into the cooling mixture contained in the vessel F and by continuously stirring the soil mass with a gentle move of the thermometer, the temperature fell very rapidly. The agitation was continued until the temperature reached the freezing point of water when it was stopped and the soil was allowed to cool undisturbed until it was supercooled to about 1.0° C. below the freezing point of water and then the tube was placed in the air jacket C of the main cooling bath and the soil mass again stirred. The soil generally commenced to solidify at once and the temperature to rise very rapidly to the proper freezing point. Before the final reading was taken, the soil mixture was thoroughly mixed by moving the thermometer. The thermometer then was set so its bulb stood in the center of the tube and did not touch the walls, tapped with the finger a few times and then the final reading recorded. The tube then was taken out of the air jacket, the thermometer placed in the stand G, and a definite quantity of $Ca(OH)_2$ was added to the soil. The thermometer was placed back into the soil, the mixture stirred for about a minute, and the process of freezing was repeated as before. The process of freezing, then adding $Ca(OH)_2$ to the soil, and refreezing was continued until the maximum lime requirement of the soil was attained, which was indicated by a change in the reading of the thermometer and hence of the freezing point depression.

In order to reduce the number of determinations made and thereby cut down on the length of time, large quantities of $Ca(OH)_2$ were first added. The method which proved most convenient consisted of adding to the soil first 5 c. c. of $N/25$ $Ca(OH)_2$. If the depression of the soil was still the same as before or less, then 5 c. c. more of $Ca(OH)_2$ was added. If the freezing point depression at the end of the third determination was greater than that of the preceding that indicated that the maximum lime requirement of the soil had been attained and surpassed, i. e., an excess of lime had been added. From the difference in the depression between the second and third determination it could be easily estimated what would be the approximate lime requirement, and with this knowledge as a guide the exact quantity was determined in a second sample of soil. Thus, for example, supposing that 2 grams of soil plus 10 c. c. of water gave a depression of .010° C. Adding 5 c. c. of $N/25$ $Ca(OH)_2$ to the mixture the depression still remained at .010° C. Adding 5 c. c. more of $Ca(OH)_2$ the depression changed to .012° C., or a difference of .002° C. The lime requirement of this soil, therefore, lay between 5 and 10 c. c. of $Ca(OH)_2$; but does it lie nearer the 5 or 10 c. c.? Information concerning this point could be obtained by knowing the depression of 5 and 10 c. c. of $N/25$ $Ca(OH)_2$ diluted in 20 c. c. of distilled water—the amount which had been added to the soil. Supposing the depression of 5 c. c. of $N/25$ $Ca(OH)_2$ in 20 c. c. of distilled water was .020° C., and 10 c. c. in 20 c. c. of water was .035° C. From these figures it could be readily judged that the true lime requirement was closer to the 10 c. c. than to the 5 c. c. of $Ca(OH)_2$ since the change in the depression was only .002° C. A second sample of soil therefore, was taken and instead of adding 5 c. c. of $Ca(OH)_2$ at first 8 c. c. were added and then the additional amounts were added in portions of 1 c. c. in order to obtain the accurate value. If a soil, however, in 2 gram portion, required only 2 c. c. of $Ca(OH)_2$ and were added to it at first 5 c. c., the depression in the second determination would be far greater than that of the soil plus water alone. By applying the same principle as above as to whether the true lime requirement lay closer to 2 or 5 c. c. the exact amount could be determined in a second sample of soil. After one is accustomed to the method, however, he can estimate accurately almost down to 0.5 c. c. without having to employ a second sample of soil.

From the above detailed description of the procedure of the method, it might appear that the method is very complicated, tedious, and time-consuming. Fortunately none of these objections is applicable to it. On the contrary, the method is very simple, extremely rapid, and quite accurate.

As to its simplicity, it must have already been seen from the description that there is practically no procedure in the method which requires an unusual amount of skill or technique. Anyone who has never performed freezing point determinations might imagine that the method is complicated but those who have made such studies will readily admit the simplicity of operation of the method.

Probably one of the most favorable virtues of this method is its rapidity of execution. As it is now developed, the freezing point method can determine the lime requirement of a soil from 10 to 15 minutes if a duplication is not necessary. It has determined the lime requirement of many soils in less than 10 minutes. This exceeding rapidity of execution lies in the fact that by bringing the tube containing the soil mixture in direct contact with the cooling mixture and keeping the soil mixture stirred with the thermometer, the temperature falls very rapidly, and the desired super-cooling is attained in a very few minutes,—as contrasted with the long time that it takes if the soil were cooled in the air jacket.

At this point the question may be raised as to the value and accuracy of the method for determining the lime requirement of soils in such an exceedingly short period of time, since the reaction between the $Ca(OH)_2$ and the soil may not be completed in that short period. It must be declared at once that this particular point was subjected to a thorough examination, and the results obtained have led to the interesting conclusion that the reaction between the $Ca(OH)_2$ and the soil, under the condition in which the experiments are performed, is exceedingly rapid if not almost instantaneous. Many experiments were performed wherein the soils were treated with slightly larger amounts of lime than they required, as determined during the short period of the operation, and allowed to stand for 6 to 24 hours. At the end of these periods the freezing point depression showed that the soils did not take up any more lime.

The remarkable rapidity of the completion of the reaction between the soil and $Ca(OH)_2$ is supported by other experiments which the writer has performed; as well as the observations of other investigators. In performing experiments, for instance, by the freezing point method to determine the effect of application of soluble chemical compounds upon the concentration of the soil solution, it was found that, with few exceptions, the magnitude of the concentration or depression produced, immediately after the salt solution was added to the soil and at the end of 24 hours, was practically the same.

In studying the absorption of the base of different salts by the soil, various investigators have noticed that the reaction is very rapid. Especially interesting in this connection is the work of Gedroiz[7] upon the speed of exchange reaction in soils. Gedroiz found that the Ca could be replaced from the soil by NH_4 and Na of the NH_4Cl and NaCl salt solutions almost immediately.

From all these evidences, then, it might be accepted as an established fact that the reaction between the soil and $Ca(OH)_2$ is completed very rapidly if not almost instantaneously, and that practically no error enters in the results from this source.

Besides its simplicity and exceeding rapidity, the freezing point method appears to be also quite accurate, at least from the practical standpoint, in determining the lime requirement of soils. The accuracy seems to vary directly with the lime requirement. If the soil requires about 10,000 pounds CaO per 2,000,000 pounds of soil there is probably an error of about 1,000 pounds CaO. If on the other hand, the soil requires only about 1,000 pounds of CaO per acre the error is probably about 200 or 300 pounds. The reason that the total error is greater when the lime requirement is high is that the volume of water present is large and the depression caused by 1 c. c. of N/25 $Ca(OH)_2$ for instance, is small as compared to that when the volume of water is less. Since the thermometer cannot be depended upon to read accurately, closer than .002° C. it is easier to make a greater total error, although a smaller percentage of error, in the greater lime requirement than in the small.

If a larger amount of soil were used doubtless the percentage of error in both cases would be greatly decreased. By using only 2 grams of soil an error of only 1 c. c. of N/25 $Ca(OH)_2$ is equivalent to 1,121.8 pounds of CaO in 2,000,000 pounds of soil. The reason that a larger amount of soil is not used is that the concentration of the $Ca(OH)_2$ solution cannot be increased in water above twenty-fifth normality. Consequently, it is necessary to add a large amount of the solution of this strength to the soils possessing a high lime requirement, and the soil tube being of small volume cannot hold all the mass if larger amounts of soil were used. Of course a tube of larger volume could be employed but this may not be advisable.

Mention has already been made that it is advisable to use in the first determinations large amounts of $Ca(OH)_2$ in order to obtain the limits more quickly, and if necessary to employ smaller quantities in a second set of determinations to obtain the exact amount of $Ca(OH)_2$ required. It should also be stated, however, that it is not advisable to add less than 1 c. c. of $Ca(OH)_2$ in the case of soils which require a large amount of lime; in the case of soils, however, which take up about 1,000 pounds CaO to the acre, less than 1 c. c. might be added each time. The reason for not adding less than 1 c. c. to the soils which possess a high lime requirement becomes evident from what has already been said. In the

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(7) Russ. J. f. Expt. Landw. Vol. 15. No. 3, 1914.

first place, the thermometer cannot be depended upon to read accurately closr than .002° C., and in the second place, less than 1 c. c. of N/25 $Ca(OH)_2$ in a large volume of water produces such a small depression that it might not be detected. It is just as accurate, therefore, to add 1 c. c. portions and estimate the tenths, using the magnitude of the depression as a guide.

Finally, the sources of error that might arise from the thermometer and the cooling bath should be mentioned. It has been found that the reading and hence the standardization of the thermometer will suddenly change. This does not happen always, but it does occur occasionally. If the change should occur during a series of titrations of a single soil, and the determination is not checked by a second sample of soil, wrong results will of course be obtained. No definite explanation can be offered for this sudden change of the thermometer. It should be stated, however, that in spite of this occasional uncertain change the Beckmann thermometer is ideally adapted for the determination of the lime requirement of soils, because its zero point is automatically determined every 10 or 15 minutes and for every soil sample. Furthermore, after one is accustomed to the character of the results he can generally detect any change in the thermometer that has taken place. It might be stated in passing that an instrument which is far more accurate and exceedingly more sensitive than the Beckmann thermometer is the thermo-element. A thermo-element can be readily made to read to .0001° C., or ten times more sensitive than the Beckmann thermometer. This instrument, however, is not very convenient to use.

For the determination of the lime requirement of soils by the freezing point method it has been found essential to keep the temperature of the cooling mixture in both vessels about –2° C. If the temperature of the cooling mixture in vessel F, where the soil is first cooled, is greater than –2° C. the soil will commence to solidify before supercooling has taken place, but if it is only about –2° C. the soil will not start to solidify until it is supercooled to about 1° C., and sometimes it can even be gently stirred while it is supercooling.

It might appear that the procedure of stirring the soil mass with the thermometer itself and not employing a regular stirrer, might introduce some error. It is believed, however, that no measurable error arises from this source. The use of the thermometer as a stirrer is of great convenience.

It should be again emphasized that the soil mass must be thoroughly mixed, care must be exercised that the bulb of the thermometer does not touch the walls of the tube, and that the thermometer should be tapped before the final reading is taken.

If the above procedure is carefully followed, it is firmly believed that any scientific man can determine the lime requirement of soils with high accuracy and definiteness.

Having given then a brief exposition of the principles underlying the method, and a rather detailed description of the apparatus and procedure, the presentation of the experimental data obtained, is next in order.

EXPERIMENTAL DATA.

THE LIME REQUIREMENT OF SOILS.

In accordance with the foregoing method, the lime requirement of a large number of soils was determined. Some of these soils were collected at random near the vicinity of this Experiment Station, others came from different parts of this State, and still others were specially obtained from other States. All these soils received no other treatment except drying in the air. In Table 5 there are presented only a few of the soils employed and their respective lime requirement. The lime requirement is expressed in number of c. c. of N/25 $Ca(OH)_2$ taken up by 2 grams of soil and in pounds of CaO in 2,000,000 pounds of soil in the case of the mineral soils, and 1,000,000 pounds in the case of the peats and mucks.

TABLE 5. LIME REQUIREMENT OF SOILS.

	Soils.	No. c. c. N/25$Ca(OH)_2$ absorbed by 2 grs. Soils.	Pounds CaO in 2,000,000 pounds soil.
1.	Quartz sand	0	0
2.	Kaolin	.5	560.9
3.	Heavy silt loam (gray)	6.0	6,730.8
4.	Heavy silt loam (black)	9.0	10,096.2
5.	Heavy clay loam (brown)	8.5	9,535.3
6.	Heavy silt loam (black)	9.0	10,096.2
7.	Light clay loam (black)	6.0	6,730.8
8.	Heavy silt loam (black)	7.5	8,412.5
9.	Light clay loam (gray)	4.0	4,487.2
10.	Heavy silt loam (gray)	3.5	3,926.3
11.	Light silt loam (black)	3.5	3,926.3
12.	Heavy silt loam (gray)	3.5	3,926.3
13.	Very light silt loam (black)	3.5	3,926.3
14.	Heavy sandy loam (black)	6.0	6,730.8
15.	Light silt loam (gray)	9.0	10,096.2
16.	Coarse sand (brown)	3.5	3,926.3
17.	Coarse sand (brown)	6.0	6,730.8
18.	Medium sand (gray)	1.0	1,121.8
19.	Light sandy loam (black)	2.0	2,243.6
20.	Very fine sandy loam (brown)	1.5	1,682.7
21.	Heavy sand (brown)	3.5	3,926.3
22.	Very fine sandy loam (brown)	4.5	5,048.1
23.	Light silt loam (black)	2.0	2,243.6
24.	Light silt loam (brown)	4.0	4,487.2
25.	Light silt loam (brown)	4.0	4,487.2
26.	Light silt loam (brown)	4.0	4,487.2
27.	Light silt loam (brown)	4.0	4,487.2
28.	Peat	30.0	16,827.0
29.	Peat	28.0	15,705.2
30.	Peat	30.0	16,827.0

An examination of the above table will at once show that the lime requirement of different soils varies greatly, according to the freezing point method, the amounts varying from 0 in the case of pure quartz sand, to 10,096.2 pounds in heavy loams, to 16,827.0 pounds in peats, of

CaO per acre. It appears that the peats, clay loams and silt loams take up larger amounts of lime than the sands and sandy loams, although in some cases the sands and sandy loams consume as much as the clay loams, and silt loams. Soil No. 17, for instance, is a coarse sand, and its lime requirement is the same as that of heavy silt loam No. 3, which is 6,730.8 pounds CaO. Soils No. 20, 31, and 32 were obtained from the Rhode Island Experiment Station through the kindness of Director Hartwell. All these three soils were considered to be acid. Soil No. 22 refused to produce satisfactory crops, according to Dr. Hartwell. This soil may be classed as very fine sandy loam and yet its lime requirement is very high. Soil No. 15 is a light silt loam and was kindly furnished by Prof. A. J. Patten of this Station. It was considered to be very acid as it turned the blue litmus paper red and showed a large lime requirement by the Veitch method. Soils No. 24, 25, 26 and 27 are light silt loams and were procured from the Pennsylvania Experiment Station plots through the kindness of Prof. J. W. White. All these soils were supposed to be acid. Soils No. 27, 29, and 30 are peats and show a tremendous lime requirement. The amount shown above is based upon 1,000,000 pounds of soil; if it were based upon 2,000,000 pounds as in the case of the mineral soils, it would be twice as large.

In order to see how the above lime requirements obtained by the freezing point method, compared with those by the Veitch method, Prof. A. J. Patten kindly determined the lime requirement of soils No. 3, 4, 15, and 16 by the latter method. These values are contained in Table 6. For direct and convenient comparison the corresponding values indicated by the freezing point method are repeated in this table.

TABLE 6. COMPARISON OF LIME REQUIREMENT OF SOILS BY THE VEITCH AND FREEZING POINT METHODS.

	Pounds CaO per 2,000,000 lbs. soil.	
	Freezing point method.	Veitch method.
Soil No. 3	6,730.8	560
Soil No. 4	10,096.2	0
Soil No. 15	10,096.2	3,780
Soil No. 16	3,926.3	1,890

It is readily seen that the results yielded by the two methods do not at all agree. The freezing point method indicates a far greater lime requirement of every soil than the Veitch method.

If to any one of the soils contained in Table 5 is added only half of the amount of CaO indicated by the freezing point method, and the ratio of soil to water is 1 to 5, the red litmus paper will immediately or shortly turn blue. This, however, is found to be true even with the Veitch method, and it is a pure case of hydrolysis, as already discussed.

It will now be of interest to ascertain the type of curve that the various soils in Table 5 yield. In Table 7 there are presented the numerical data of a few examples which are typical of the various classes of soil. These results are graphically represented in figures 6a, 6b, 6c and 6d.

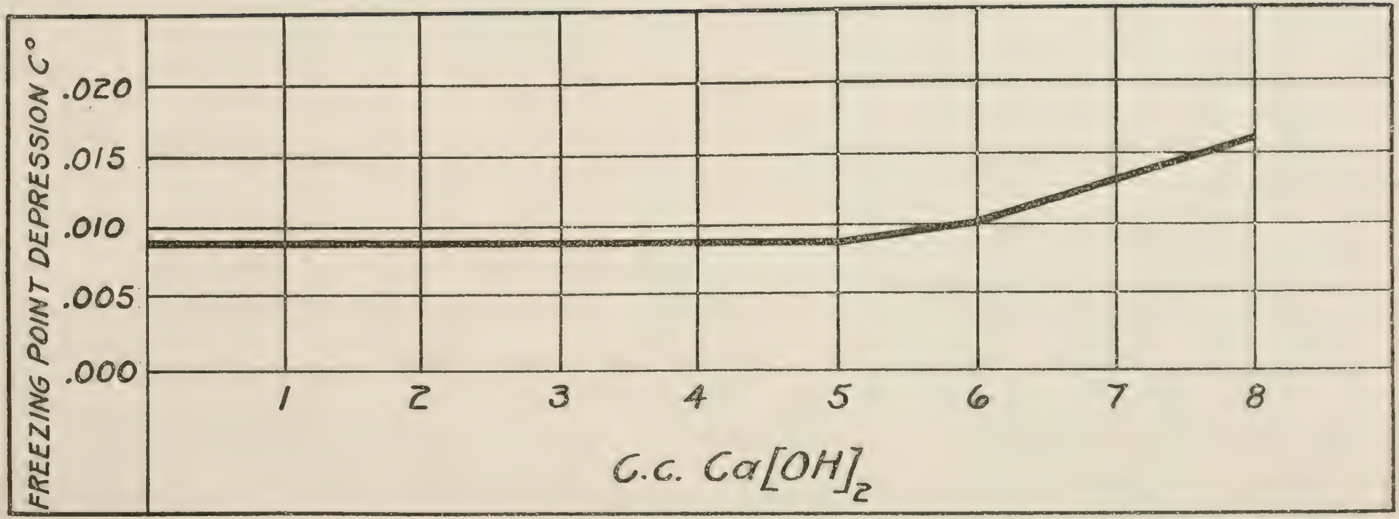

FIGURE 6a. Curve showing the constancy of the depression of mineral soils by the successive addition of $Ca(OH)_2$ up to a certain point and then the increase with further addition of $Ca(OH)_2$

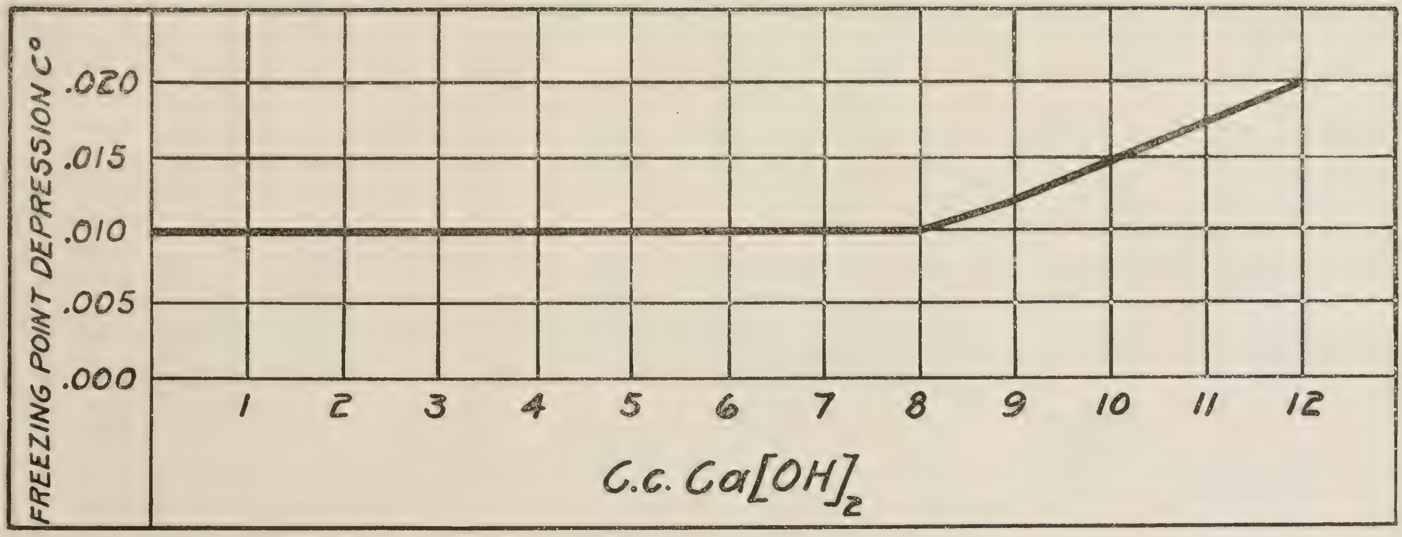

FIGURE 6b. Curve showing the constancy of the depression of mineral soils by the successive addition of $Ca(OH)_2$ up to a certain point and then the increase with the further addition of $Ca(OH)_2$

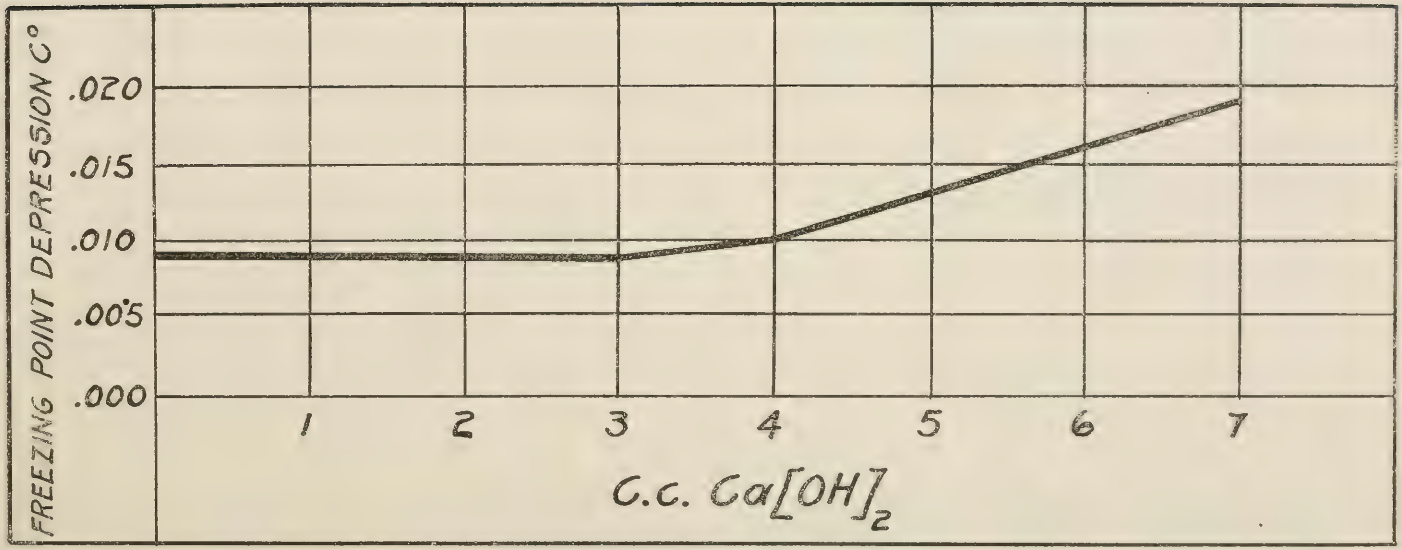

FIGURE 6c. Curve showing the constancy of the depression of mineral soils by the successive addition of $Ca(OH)_2$ up to a certain point and then the increase with the further addition of $Ca(OH)_2$

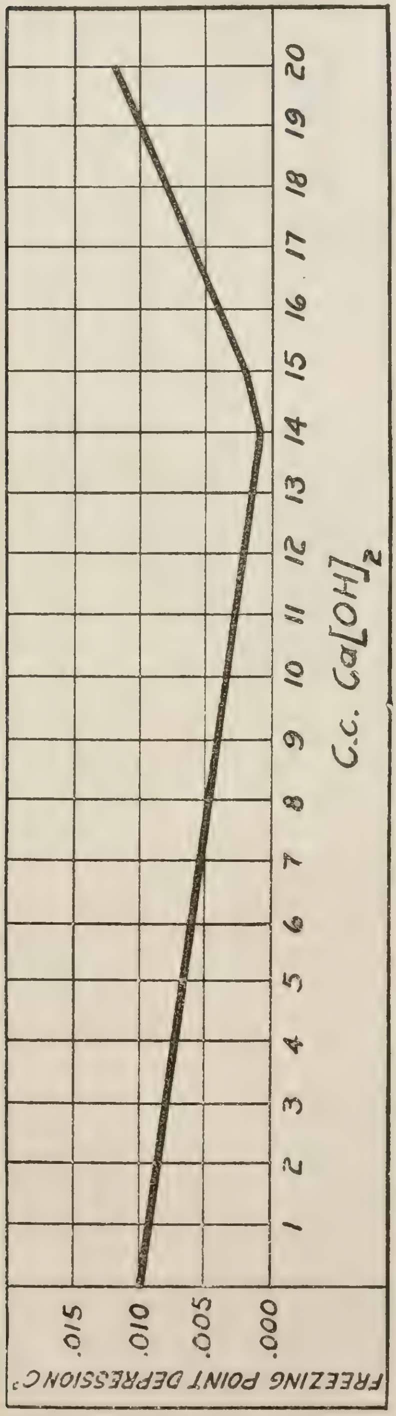

FIGURE 6d. Curve showing the decrease in the depression of peat by the addition of $Ca(OH)_2$ down to a certain point and then the increase with the further addition of $Ca(OH)_2$

TABLE 7. THE FREEZING POINT DEPRESSION OF SOILS TO WHICH WERE ADDED VARIOUS QUANTITIES OF $Ca(OH)_2$.

Reagents.	Depression.
2 gm. Soil No. 3 plus 10 c. c. water	.009°C
plus 5 c. c. N/25 $Ca(OH)_2$	.009
plus 1 c. c. N/25 $Ca(OH)_2$	.010
plus 2 c. c. N/25 $Ca(OH)_2$	.016
2 gm. Soil No. 4 plus 10 c. c. water	.010°C
plus 8 c. c. N/25 $Ca(OH)_2$	.010
plus 1 c. c. N/25 $Ca(OH)_2$	.012
plus 3 c. c. N/25 $Ca(OH)_2$	.020
2 gm. Soil No. 9 plus 10 c. c. water	.009°C
plus 3 c. c. N/25 $Ca(OH)_2$	.009
plus 1 c. c. N/25 $Ca(OH)_2$	.010
plus 3 c. c. N/25 $Ca(OH)_2$	.019
1 gm. Peat No. 30 plus 10 c. c. water	.010°C
plus 14 c. c. N/25 $Ca(OH)_2$	.001
plus 1 c. c. N/25 $Ca(OH)_2$	.002
plus 5 c. c. N/25 $Ca(OH)_2$	.012

It is clearly evident that both the absorption and acid curves are obtained. It will be noted, however, that only the peats gave an acid curve, while the mineral soils yielded the absorption curve. Since the above examples are presented to typify the general character of curve that all the different soils in their natural condition yielded, then it will at once be inferred that only the peats and mucks yielded the acid curve while the mineral soils gave the absorption curve. Indeed nearly 80 different mineral soils have been tested by the freezing point method both for their lime requirement and nature of their acidity and in no case was an acid curve obtained. This array of soils included some of the most acid soils of the Rhode Island and Pennsylvania experimental plots. On the other hand, most of the peats, which numbered only 15, and collected at random, gave an acid curve.

Although none of the 80 mineral soils tested failed to give an acid curve, it cannot be concluded that universally all mineral soils will act alike. On the contrary there are probably some mineral soils which would give an acid curve, but it is believed that such soils are rare. On the other hand, probably all the mineral soils under humid conditions can be induced, by certain treatments, to give an acid curve, as will be subsequently shown.

The curve yielded by the mineral soils and designated for convenience an absorption curve is of great significance and warrants a thorough consideration. Indeed, this type of curve throws light upon the nature of the acidity of mineral soils, and also upon the theory of exchange of bases in soils.

In the first place this absorption curve shows that the $Ca(OH)_2$ is removed from solution or taken up by the soil as fast as it is added and is rendered inactive as far as the freezing point depression is concerned, until a certain point is reached and then it begins to remain in solution, or if it is still taken up, it replaces something else, most likely another base. Now the substance which uses up the $Ca(OH)_2$ must be in the solid phase and not in the liquid phase, for if it were in the liquid phase the depression would not remain constant. If the substance were in solution it would take part in the depression produced by the soil plus the water. Upon the addition of $Ca(OH)_2$ a reaction would take place. If the reaction resulted in an insoluble product the substance would be removed from the solution and thus decrease the freezing point depression. If, on the other hand, the reaction resulted in a soluble compound, the depression would vary according to the degree of dissociation of this compound. Again, if the substance were in solution, then the same kind of curve should be obtained if only the soil solution alone was titrated with $Ca(OH)_2$. When the soil extract was titrated with $Ca(OH)_2$ the absorptive curve was not obtained. The type of curve that was obtained, consisted of a no-lime absorption or alkaline curve, i. e., the depression began to rise almost immediately upon the addition of a small amount of $Ca(OH)_2$ to the soil extract.

Hence the evidences are strongly in favor of the view that the $Ca(OH)_2$ *is taken up or absorbed by a substance which is not in solution and does not affect the freezing point depression. Consequently it must be in the solid form.*

The question now is, if the substance which causes the disappearance of the $Ca(OH)_2$ from the solution is solid, what is its chemical and physical composition? An attempt will now be made to answer this question.

As it is well known, the mineral soils consist largely of silica, aluminum, and iron, followed in smaller amounts by calcium, potassium, sodium and magnesium. These elements, together with others, combine to form polysilicates. The mineral constituents of the soil, therefore, consist of salts of polysilicic acids. These polysilicates being salts of weak acids with strong bases hydrolyse upon being dissolved in water, and the products of hydrolysis consist mainly of an unhydrolyzed salt, a base, and an acid. The acid, which consists probably of silicic acid, alumina-silicates, and silica is more or less insoluble. The bases, however, being more soluble, are carried away by the drainage system, or consumed by the plants, or are dissolved by inorganic and organic acids that might temporarily be formed in the soil. The residue left behind, therefore, consists mainly of silica, acid alumino-silicates, and silicic acid. These compounds possessing a high reactivity for $Ca(OH)_2$ will absorb it immediately upon its being offered to them, and combine with it to form calcium silicates. The calcium silicates are difficultly soluble.

Hence, it appears from all evidences, that the substance which causes the disappearance of the $Ca(OH)_2$ from solution consists mainly of silica, acid alumino-silicates, and silicic acid. This view is strongly supported by the investigation of McIntire, Willis and Hardy[8]. These investigators in conducting a study to determine the factors influencing the lime requirement determinations, found that when different soils were treated with large amounts of $CaCO_3$ and $MgCO_3$, these compounds were soon decomposed by the silica, acid silicates and titanium oxide, the CO_2 being dissipated, and the Ca and Mg radicals combined with the above acids to form calcium, and magnesium silicates and calcium and magnesium titanate.

On the other hand, these silica, acid silicates, and silicic acid, must be in some particular physical form, probably in the hydrated and colloidal condition, otherwise they do not seem to show any reactivity towards the $Ca(OH)_2$. Thus, for instance, quartz sand both in medium size and in extremely fine powdered form takes up practically no $Ca(OH)_2$. Again, any of the mineral soils which shows a very high lime requirement absorbs practically no $Ca(OH)_2$ after it is burned.

While the absorption of the $Ca(OH)_2$ may be attributed mainly to the

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(8) Univ. Tenn. Agr. Expt. Sta. Bull. 107. 1914.

colloidal hydrated silica, acid alumino-silicates, silicic acid, and insoluble organic matter, in the case of the mineral soils, in the case of peats and mucks, however, it might be partly assigned to the soluble organic acids and humus substances, and partly to organic insoluble acids and humus substances.

Hence, the acidity or lime requirement of soils might be ascribed almost entirely to insoluble hydrated silicic acid, acid alumino-silicates, silica, and organic insoluble substances in the case of the mineral soils, and to organic soluble acids and humus substances, and organic insoluble acids and humus substances in the case of peats and mucks.

Referring once more to the absorption curve of the mineral soils, it will be at once concluded that no exchange of bases takes place in the soil, when it is treated with $Ca(OH)_2$, until it is saturated with this base. Hence, while an exchange of bases may take place when the soil is treated with a neutral salt, such an exchange does not immediately occur when a free base is used.

Another very interesting phenomenon in connection with the absorption curve is the fact that the depression of the freezing point remains constant with the increase in the volume of water present. Thus, just before the soil is completely saturated or satisfied with $Ca(OH)_2$, the volume of water is increased in some cases almost twice and yet the lowering of the freezing point is the same. It appears that when the solution of the soil is very dilute the freezing point depression is not perceptibly affected even with considerable increase in the volume of water. Thus 2 grams of soil in 10 c. c. of water give a lowering of the freezing point of .010° C. Practically the same lowering of the freezing point is obtained when the same quantity of soil is treated with 20 c. c. of water. Even in pure salt solutions the freezing point depression remains almost constant with large dilutions, if the original solutions are very dilute. Thus, $MgSO_4$ at a certain concentration gave a depression of .010° C. Upon adding to 10 c. c. of this solution 10 c. c. of water, the depression changed to .008° C., or a difference of only .002° C. These results might be expected in the case of electrolytes.

Before concluding this part of the investigation, on the lime requirement of soils, a brief discussion should be devoted to the character of the reaction that is involved between the $Ca(OH)_2$ and the various soils, that is to say, is the reaction a chemical or a physical one? It should be at once stated that it appears to be both but the major part appears to be chemical. That probably it is not entirely physical may be mentioned the following facts: (1) The quantity of lime taken up by the various soils is too great to be accounted for entirely by surface phenomena; surface alone does not appear to be the predominant cause of the absorption because kaolin and quartz sand may be ground almost as fine as many of the clay loams here employed and yet their lime requirement is practically negligible. (2) The curves obtained are not adsorption curves; the adsorption curves are smooth equilibrium curves and consequently do not have such abrupt breaks as indicated in the foregoing curves. (3) There is no fundamental reason why the phenomenon cannot be chemical.

Lastly, the question may be asked, is it necessary and economical to add to the soil all the amount of lime according to the freezing point method, it requires? As previously declared, this question will ultimately have to be decided in the field, using the plant as indicator. All that is claimed is that the freezing point method, as a laboratory method, seems to indicate the true lime requirement of the soil. *By true lime requirement is meant the maximum specific activity that the different soils have for lime. In this maximum lime requirement there is included the lime that is necessary to neutralize any free soluble acids and acid salts, and the lime that the soil requires to satisfy its absorption-adsorption properties.* Now it is possible that this method indicates altogether too high lime requirement and when the plants are used as indicators it might be found that the plants can make just as good growth with smaller amounts as they can with the maximum. On the other hand it should be strongly emphasized that this method does not give altogether too abnormally high lime rebuirements. Indeed the maximum amounts indicated are quite in accord with some of the maximum applications that many soil authorities advise. Thus Hopkins[9] states: "It may be said, however, that 10 tons of ground limestone per acre would not only do no harm, but would probably produce somewhat larger crops than any lighter application. As much as 10 tons per acre has been applied on an experiment field in southern Illinois, and the crop yields on that field have been larger during the last three years than on any other experiment field in that area. Two to four tons per acre, however, have usually produced much benefit."

In a recent publication by Blair[10] the following statements are made in regard to the amounts of lime that might be applied to New Jersey soils: "With general farm crops on a loam to clay loam, 1,500 to 2,000 pounds of burned lime may be considered a moderate application. For alfalfa, 2,500 to 3,000 pounds could safely be used. For sands and sandy loams, 1,000 to 1,500 pounds would be a safe application. If the soil is known to be very acid or to contain a great deal of organic matter, a somewhat heavier application could be made," etc. Further on he says: "On wet land and muck lands as much as 5,000 to 10,000 pounds of lime may be required to correct the acidity."

It is evident, therefore, that the maximum lime requirements indicated by the freezing point method certainly appear to be in accordance with some of field practices.

THE ABSORPTION OF NaOH, KOH, AND NH_4OH BY SOILS.

In the last section the absorption of $Ca(OH)_2$ by different soils was considered. It will now be of great interest to ascertain the absorption by the same soils of other bases, namely KOH, NaOH, and NH_4OH. The absorption of these bases by the various soils represented in Table 5 was determined exactly in the same way as that of $Ca(OH)_2$ already considered. The solutions of these hydrates were diluted to such an extent that their freezing point depression was about the same as that of $Ca(OH)_2$—a little over .100° C. Their strength, however, was determined by titration and the necessary calculations made therefrom. Table 8 contains the amount of these bases taken up by the same soils used in the case of $Ca(OH)_2$. The quantity absorbed is expressed in number of c. c. of the hydrate per 2 grams of soil. For convenient and direct comparison the required $Ca(OH)_2$ by the same soils is also reproduced in this table.

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(9) Soil Fertility and Permanent Agriculture, 1910, p. 173.
(10) Circular 54, New Jersey Agr. Expt. Sta., 1916.

TABLE 8. THE ABSORPTION OF DIFFERENT HYDRATES BY VARIOUS SOILS.

	Kind of Soil.	No. c c. N/25 Hydrate absorbed by 2 grams of Soil.			
		$Ca(OH)_2$	KOH	NaOH	NH_4OH
1.	Heavy silt loam (gray)	6.0	5.5	2.4	2.1
2.	Heavy silt loam (black)	9.0	5.5	4.8	2.6
3.	Heavy clay loam (brown)	8.5	5.5	5.0	2.4
4.	Heavy silt loam (black)	9.0	5.5	5.0	2.5
5.	Light clay loam (black)	6.0	2.5	2.4	1.2
6.	Heavy silt loam (black)	7.5	2.5	2.4	2.1
7.	Light clay loam (gray)	4.0	2.5	2.4	1.8
8.	Heavy silt loam (gray)	3.5	2.5	2.4	1.8
9.	Light silt loam (black)	3.5	2.5	1.8	0.9
10.	Heavy silt loam (gray)	3.5	2.5	1.8	1.2
11.	Very light silt loam (black)	3.5	2.5	1.8	1.2
12.	Heavy sandy loam (black)	6.0	2.5	2.4	1.5

The foregoing data reveal at once the remarkable fact that the amount of base taken up by any one soil differs markedly with the various bases. In other words, the soils do not absorb the various bases in chemically equivalent quantities. All soils take up $Ca(OH)_2$ in greatest quantity followed by KOH, NaOH, and NH_4OH in order respectively. The various soils, also, do not absorb these various hydroxides in the same relative ratio.

Evidently, therefore, each soil possesses a specific reactivity for the different hydroxides.

It will now be of interest to ascertain whether a soil which is already satisfied with one base will still take up other bases. That is to say, if a soil is satisfied with the amount of NH_4OH it requires, will it take up any more of $Ca(OH)_2$ and *vice versa*. To obtain information upon this question the problem was attacked in the following manner: The exact requirement of a soil for $Ca(OH)_2$, KOH, NaOH, and NH_4OH was first ascertained in the usual manner. Then to this soil was added a little more than the true requirement of any one base and its freezing point depression determined. To this mixture was then added various quantities of another base until the depression began to change. If the depression began to change immediately upon the addition of a small amount of the second base then it was considered that the soil would not take up another base, i. e., cause it to disappear. Some of the data obtained are as follows:

2 gm. Soil No. 1 originally required 6 c. c. N/25 $Ca(OH)_2$ to cause change in depression, required only 1 c. c. after it received 2.5 c. c. N/25 NH_4OH.

2 gm. Soil No. 2 originally required 9 c. c. N/25 $Ca(OH)_2$ to cause change in depression, required only 1.5 c. c. after it received 3 c. c. N/25 NH_4OH.

2 gm. Soil No. 3 required 8.5 c. c. N/25 $Ca(OH)_2$ to cause change in the depression, required only 1.5 c. c. after it received 3 c. c. N/25 NH_4OH.

2 gm. Soil No. 1 originally required 5.5 c. c. N/25 KOH to cause change in the depression, required only 1 c. c. after it received 7 c. c. N/25 $Ca(OH)_2$.

2 gm. Soil No. 2 originally required 5.5 c. c. N/25 KOH to cause

change in depression, required only 1 c. c. after it received 10 c. c. N/25 $Ca(OH)_2$

2 gm. Soil No. 3 originally required 5.5 c. c. N/25 KOH to cause change in the depression, required only 1 c. c. after it received 9 c. c. N/25 $Ca(OH)_2$.

2 gm. Soil No. 1 originally required 6 c. c. N/25 $Ca(OH)_2$ to cause change in depression, required only 1 c. c. after it received 6 c. c. N/25 KOH.

2 gm. Soil No. 2 originally required 9 c. c. N/25 $Ca(OH)_2$ to cause change in depression, required only 1.5 c. c. after it received 6 c. c. N/25 KOH.

2 gm. Soil No. 3 originally required 8.5 c. c. N/25 $Ca(OH)_2$ to cause change in depression, required only 1.5 c. c. after it received 6 c. c. N/25 KOH.

It becomes at once evident from the above tabulated data, therefore, that when a soil is saturated or satisfied with a particular base it will absorb very little if any of another base, even though the various bases are absorbed in non-equivalent amounts.

On the other hand, when a soil is only partly satisfied with one base it will take up a correspondingly large amount of another. Thus for instance, when a soil in 2 gm. portion required and received 3.5 c. c. N/25 KOH, the addition of only 1 c. c. N/25 $Ca(OH)_2$ caused a change in the depression. On the other hand, when only 2.5 c. c. N/25 KOH was added to this soil, it required 7 c. c. N/25 $Ca(OH)_2$ to cause a change in the depression. This was true in the case of all bases.

Just what is the true explanation of this unequal absorption of the various hydrates by the same kind of soils cannot be stated at this time. It is evident, however, that it follows some definite and significant laws. The problem is under special investigation and it is hoped the true explanation will be discovered.

Finally, it should be stated that this unequal absorption of the various hydrates, does not appear at present to be a point against the freezing point method, for determining the lime requirements of soils. On the contrary, it points to some phenomena which promise to be of significant theoretical interest and of important practical value.

EFFECT OF ACIDS AND ACID SALTS UPON THE LIME REQUIREMENT OF SOILS.

Thus far the lime requirement of only natural untreated soils has been considered. The question will now be taken up of the effect of acids, acid salts, and neutral salts upon the lime requirement of soils. Since the data dealing with the acid and acid salt treatments illustrate certain fundamental principles which are necessary for a convenient and successful discussion of the data pertaining to the neutral salt treatments, they will be considered first.

The research on the effect of acids, and acid salts upon the lime requirement of soils consisted (1) of adding to 2 grams of soil various amounts of inorganic and organic acids, and inorganic acid salts and then determining its lime requirement; and (2) treating the soil with an excess of acid, then washing it with water, drying it in the air, and its lime requirement determined. In Table 9 there are presented the lime requirements of four different soils to which were added 10 c. c. of dilute (about N/100) HCl and dilute $Al_2(NO_3)_6$ in 2 gm. portion of soil, and also the requirement before treatment. These data will serve to typify the general results that were obtained by treating different soils with H_2SO_4, HNO_3, $H_2C_2O_4$, $AlCl_3$, $Fe(NO_3)_3$, etc. Table 10 contains the lime requirement of three different soils which were treated with an excess of dilute (N/100) HCl and then washed and dried.

TABLE 9. LIME REQUIREMENT OF SOILS TO WHICH WERE ADDED HCl AND $Al_2(NO_3)_3$.

Soil.	HCl		$Al_2(NO_3)_6$	
	c.c. N/25 $Ca(OH)_2$ per 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ per gm. 2 soil.	Pounds CaO per acre.
Soil No. 1 before treatment	6	6,730.8	6	6,730.8
Soil No. 1 after treatment	9.5	10,657.1	11	12,339.8
Soil No. 2 before treatment	9	10,096.2	9	10,096.2
Soil No. 2 after treatment	12.5	14,022.5	14.5	15,144.3
Soil No. 3 before treatment	8.5	9,535.3	....	....
Soil No. 3 after treatment	12	13,461.6	....	....
Soil No. 4 before treatment	4	4,487.2	....	....
Soil No. 4 after treatment	7.5	8,413.5	....	....

TABLE 10. LIME REQUIREMENT OF SOILS WHICH WERE TREATED WITH DILUTE HCl, WASHED, AND DRIED.

Soil.	c.c. N/25 $Ca(OH)_2$ per 2 gm. soil.	Pounds CaO per acre.
Soil No. 1 before treatment	6	6,730.
Soil No. 1 after treatment	8	8,974.4
Soil No. 2 before treatment	9	10,096.2
Soil No. 2 after treatment	12	13,461.6
Soil No. 3 before treatment	8.5	9,525.3
Soil No. 3 after treatment	11	12,339.8

Considering first the data in Table 9 it will be immediately seen that the presence of 10 c. c. of either HCl or $Al_2(NO_3)_6$ in 2 gram portion of soil increased the lime requirement markedly. In the case of the HCl the increase over the untreated soils is about the same for all soils and amounts to about 3 c. c. N/25 $Ca(OH)_2$ or about 3,365 pounds CaO per acre. In the case of the $Al_2(NO_3)_6$ the magnitude of the increase is also approximately the same for all soils, and is about 5 c. c. of N/25 $Ca(OH)_2$ or 5,609 pounds CaO per acre.

In many experiments not here repeated the amounts of HCl or $Al_2(NO_3)_6$ added to 2 grams of soil were gradually increased from 0 to 10 c. c. by 2 c. c. portions. In every case the lime requirement of the soil increased directly with the amount of the acid or acid salt added.

The magnitude of the increase of the lime requirement of the soils appears to be approximately equal to the amount of lime required to neutralize the quantity of the acid or acid salt added. Thus, 10 c. c. of HCl of the strength employed required 2.8 c. c. of N/25 $Ca(OH)_2$ to be neutralized, while 10 c. c. of $Al_2(NO_3)_6$ solution took up nearly 6 c. c. of

N/25 $Ca(OH)_2$ before a change in the color of the indicator occurred, using phenolphthalein as indicator. Practically identical results were obtained when the titration of the acid and acid salt was performed by the freezing point method.

Besides the HCl, and $Al_2(NO_3)_6$ other acids and acid salts were used, such as HNO_3, H_2SO_4, $AlCl_3$, $Fe(NO_3)_3$, etc. The data obtained coincide in principle with those above.

Referring now to Table 10, which contains the lime requirement of soils which were treated with HCl, then washed and dried, it will be observed that even this form of treatment increased the lime requirement. The increase in all soils is considerable.

In the case of the unwashed soils to which were added the acid or acid salts, the freezing point depression decreased with successive additions of $Ca(OH)_2$ until a point was reached, the neutralization-absorption point, and then it began to increase with further addition of the base. The data then plotted into an acid curve similar to that obtained when the acid and acid salt were titrated by the same hydrate. If there was present only a very small amount of the acid or acid salt, however, this acid curve could not be obtained, at least very pronouncedly, which would be naturally expected.

In the case of the soils, however, which were treated with an excess of acid and then washed for long time, the freezing point depression remained constant with successive additions of $Ca(OH)_2$ until a certain amount was added and then it began to increase. The results then plotted into an absorption curve similar to that of the untreated soils. The acid, or the substance which produced the acid curve, when the soils were treated with an acid, was evidently removed by washing with water, although an increase in the lime requirement still remained.

The foregoing general facts finally led to the desire to ascertain whether the strength of an acid changes when it is added to a soil which shows a large lime requirement by the freezing point method. For obtaining information upon this question the following experiment was performed. A soil which showed a lime requirement of about 10,000 pounds CaO per acre was treated with N/100 HCl in the ratio of 10 grams of soil to 50 c. c. of the acid. The mixture was stirred thoroughly for a few minutes and allowed to stand until the supernatant liquid was clear. Then about 15 c. c. of this supernatant liquid was taken, without filtering, and titrated with $Ca(OH)_2$, according to the freezing point method. To our surprise it was discovered that this supernatant liquid failed to give an acid curve, and the depression began to increase almost immediately upon adding about 2 c. c. N/25 $Ca(OH)_2$, indicating that the liquid contained very little if any acid. Some more of the supernatant liquid was taken out and tested for acidity with the litmus paper. True enough the liquid was neutral or very slightly acid. It was at once suggested that the acid or substance which gives the acid curve must be in the soil mass. All the remaining supernatant liquid then was poured off, the soil placed in the freezing point tube and titrated in the regular manner. The results gave an acid curve as usual. These results then tended to confirm the above suspicion that the acid must be in the soil and very little if any of it is diffused or represented in the solution which bathes the soil. Now if that is the case, it was reasoned, the blue litmus paper should turn red, when brought in intimate contact with the soil mass. This was tried and, true to the prediction, the blue litmus paper did turn red. The case then according to these series of experiments stood as follows: A soil in the natural condition showed a very high lime requirement according to the freezing point method, and gave an absorption curve. When this soil was treated with an excess of acid, the supernatant liquid was almost neutral both according to the freezing point method and the litmus paper test, while the sediment or soil mass, was acid to the litmus paper and gave an acid curve with the freezing point method. When this sediment was washed with water the acid or substance which yielded the acid curve and which was not equally represented in the supernatant liquid, disappeared.

The above series of experiments were repeated a great number of times using different soils, including some of the acid soils from the Rhode Island Experiment Station plots, and various inorganic acids, with exactly the same result.

To many soils were added as much as 60 c. c. N/100 HCl to 10 grams portions, without the supernatant liquid turning the blue litmus paper red, at least not immediately. Many of these litmus paper tests were repeated and verified by Prof. A. J. Patten and Prof. M. M. McCool.

After the foregoing series of experiments were completed there appeared an article by Rice[8] entitled "Soil Studies." In this paper Rice presents data on the basic exchange between soils and salt solutions as measured by the hydrogen ion concentration method. In connection with these studies he mentions a single experiment in which he shook two soils, which responded strongly to all the usual tests for soil acidity, with three times their quantity of N/100 HNO_3. He found, according to the hydrogen ion concentration method, that the strength of the acid added had been considerably reduced after contact with the soil. In conclusion he says: "Hence, even acid soils may neutralize acids to some extent. Whether or not, in addition, some of the acid was adsorbed by the soil was not determined."

It may be accepted then as an established fact that when a soil, which takes up a large amount of lime, is treated with an excess of acid, up to a certain extent, the supernatant liquid may be neutral or only slightly acid, while the soil mass itself is strongly acid to litmus paper and gives an acid curve with the freezing point method.

The interesting question now is, how may this phenomenon be explained? The question of neutralization of the supernatant liquid could be dispensed with at once by assuming that the bases of the soil neutralized the acid. But how about the acid remaining in the soil itself? It must be immediately declared that no satisfactory explanation can be offered at this time for the latter phenomenon. The problem is under special investigation and it is hoped to discover the true explanation. The following facts, however, should be recorded at this time:

The acid which remains in the soil mass and causes an acid curve to be obtained must be in solution, on two main grounds, (1) it can be removed very readily by washing with water and (2) it affects the freezing point depression, since on being neutralized with $Ca(OH)_2$ the depression of the soil is decreased, indicating that the acid combines with the base to form an insoluble compound and thereby is removed from solution, or to form a soluble salt which has a lower degree of dissociation than itself. But how and why should this soluble acid remain in the soil mass and not diffuse in the supernatant liquid which bathes the soil mass and thus be equally distributed? How is the law of equilibrium satisfied?

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[8] J. Phy. Chem., 20, 214, (1916).

It was thought that if the soil held this soluble acid by some means—adsorption or occlusion—and did not allow it to diffuse equally into the supernatant liquid—which is contrary to the law of equilibrium—then there should be a difference of concentration between the supernatant liquid and the sediment. This point could be easily verified simply by determining the freezing point depression of the clear supernatant liquid and of the sediment. The experiment was performed but the results showed that there was no difference in the depression between the solution and the soil—indicating probably that the acid might not be free and in the liquid phase, or if it were, it had replaced or caused something else to go into solution, so that there was an equilibrium between the supernatant liquid and the soil mass, as far as concentration is concerned, but not in composition.

Whatever the explanation should prove to be, this phenomenon certainly appears to be a most remarkable one.

Having studied the effect of acids and acid salts upon the lime requirement of soils and the phenomenon relating thereto, it will now be of interest to know the results obtained with neutral salts.

EFFECT OF SOLUBLE SALTS UPON THE LIME REQUIREMENT OF SOILS.

The effect of soluble salts upon the lime requirement of soils was studied in two different ways: (1) to 20 grams of soil were added 20 c. c. N/10 of a neutral salt solution, the soil allowed to dry in room temperature and its lime requirement determined according to the procedure already described; (2) to 2 grams of soil were added 2 c. c. of a N/10 salt solution, and 10 c. c. of water, and its lime requirement ascertained as usual. There were several soils used, ranging from very low to very high initial lime requirement. The salt solutions employed consisted of $NaNO_3$, KNO_3, $Ca(NO_3)_2$, KCL, K_2SO_4, $CaCl_2$, $MgSO_4$, $(NH_4)_2SO_4$, $NaC_2H_3O_2$, K_2HPO_4, and $CaH_4(PO_4)_2$ in N/10 strength. Since both methods gave essentially the same kind of results, and inasmuch as the second method is the most accurate, the results obtained by the second study will be presented here. These data are contained in Table 11.

An examination of the preceding data reveals clearly and decisively the following most important facts: (1) All the salts increased the lime requirement of the agricultural soils very markedly, but the neutral salts considerably more than the acid phosphate salts. Thus, in the case of Soil No. 2 the acid phosphate salts augmented the lime requirement by 1,121.8 pounds CaO per acre while the neutral salts increased the amount by 4,487.2 pounds; (2) All neutral salts increased the lime requirement of any one soil to the same magnitude. This was also true of the acid phosphate salts. Thus, in Soil No. 2 all the neutral salts caused an increase of 4,872 pounds CaO, and both phosphate salts, 1,121.8 pounds CaO; (3) In the case of quartz sand which originally took up no lime, none of the neutral salts caused it take up lime, but both of the phosphates did. This lime requirement, however, is due to the phosphate salts themselves and not to the quartz sand, as will subsequently be explained.

TABLE 11. EFFECT OF SALTS UPON THE LIME REQUIREMENT OF SOILS.

Number of soil.	$NaNO_3$		KNO_3		$Ca(NO_3)_2$		KCl		K_2SO_4	
	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.
No 1 untreated	6	6,730.8	6	6,730.8	6	6,730.8	6	6,730.8	6	6,730.8
No. 1 treated	10	11,218.0	8	11,218.0	10	11,218.0	10	11,218.0	10	11,218.0
No. 2 untreated	9	10,096.2	9	10,096.2	9	10,096.2	9	10,096.2	9	10,096.2
No. 2 treated	13	14,583.4	13	14,583.4	13	14,583.4	13	14,583.4	13	14,583.4
No. 3 untreated	8.5	9,535.3	8.5	9,535.3	8.5	9,535.3	8.5	9,535.3	8.5	9,535.3
No. 3 treated	12.5	14,022.5	12.5	14,022.5	12.5	14,022.5	12.5	14,022.5	12.5	14,022.5
No. 4 untreated	1	1,121.8	1	1,121.8	1	1,121.8	1	1,121.8	1	1,121.8
No. 4 treated	4	4,487.2	4	4,487.2	4	4,487.2	4	4,487.2	4	4,487.2
Quartz sand untreated	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quartz sand treated	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Number of soil.	$MgSO_4$		$(NH_4)_2SO_4$		$NaC_2H_3O_2$		K_2HPO_4		$CaH_4(PO_4)_2$	
	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.
No 1 untreated	6	6,730.8	6	6,730.8	6	6,730.8	6	6,730.8	6	6,730.8
No. 1 treated	10	11,218.0	10	11,218.0	10	11,218.0	9	10,096.2	9	10,096.2
No. 2 untreated	9	10,096.2	9	10,096.2	9	10,096.2	9	10,096.2	9	10,096.2
No. 2 treated	13	14,583.4	13	14,583.4	13	14,583.4	10	11,218.0	10	11,218.0
No. 3 untreated	8.5	9,535.3	8.5	9,535.3	8.5	9,535.3	8.5	9,535.3	8.5	9,535.3
No. 3 treated	12.5	14,022.5	12.5	14,022.5	12.5	14,022.5	10	11,218.0	10	11,218.0
No. 4 untreated	1	1,121.8	1	1,121.8	1	1,121.8	1	1,121.8	1	1,121.8
No. 4 treated	4	4,487.2	4	4,487.2	4	4,487.2	4	4,487.2	4	4,487.2
Quartz sand untreated	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quartz sand treated	0	0.0	0	0.0	0	0.0	3	3,365.4	3	3,365.4

Evidently, therefore, the application of soluble salts increases the lime requirements of soils quite markedly. The question now is, is this increase permanent or only temporary, and in either case how is it brought about?

To procure information upon these questions the following line of research was pursued: To 20 grams of soil were added 20 c. c. of any one of the salt solutions. The ratio of the soil to the solution and the strength of the solution were the same as above. The mixture was stirred and allowed to stand for about an hour. Then the mixture was poured upon a filter paper in a funnel and washed with water. The soil was allowed to dry in room temperature and its lime requirement was determined in the usual manner. The results obtained are detailed in **Table 12.**

TABLE 12. LIME REQUIREMENT OF SOILS WHICH WERE TREATED WITH SALT SOLUTIONS AND THEN WASHED.

Soil.	$NaNO_3$		K_2SO_4	
	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.	c.c. N/25 $Ca(OH)_2$ absorbed by 2 gm. soil.	Pounds CaO per acre.
Soil No. 1 untreated	6	6,730.8	6	6,730.8
Soil No. 1 treated	6	6,730.8	6	6,730.8
Soil No. 2 untreated	9	10,096.2	9	10,096.2
Soil No. 2 treated	9	10,096.2	9	10,096.2
Soil No. 3 untreated	8.5	9,535.3	8.5	9,535.3
Soil No. 3 treated	8.0	8.974.4	8.5	8,974.4

The data in the above table are highly interesting and very significant. They show that the soils which were treated with various salt solutions and then washed, have practically the same lime requirement as that before treatment. In other words, the substance which increases their lime requirement when they are treated with the soluble salts disappears upon washing, and they come back to their original lime requirement.

These data then go to prove three main facts, (1) *The substance which caused an increase in the lime requirement of the soil upon being treated with the soluble salts was soluble or in solution and was readily carried away by washing,* (2) *The treatment did not produce any permanent change in the soil, either chemical or physical and consequently* (3) *the increase in lime requirement brought about by the application of soluble salts was only temporary and not permanent.*

Now what is the nature of the substance which is produced in the soil by the salts, and is readily soluble or in solution, that causes the increase in the lime requirement. Before attempting to answer this question it is essential to consider first the type of curve that the soils containing the substance, i. e., the soils which are treated with the salt solution and not washed, will yield upon being titrated with $Ca(OH)_2$ according to the freezing point method. The data pertaining to this phase of the investigation are contained in Table 13 and graphically represented in figures 7a, 7b, 7c and 7d. Only a few typical examples are here submitted.

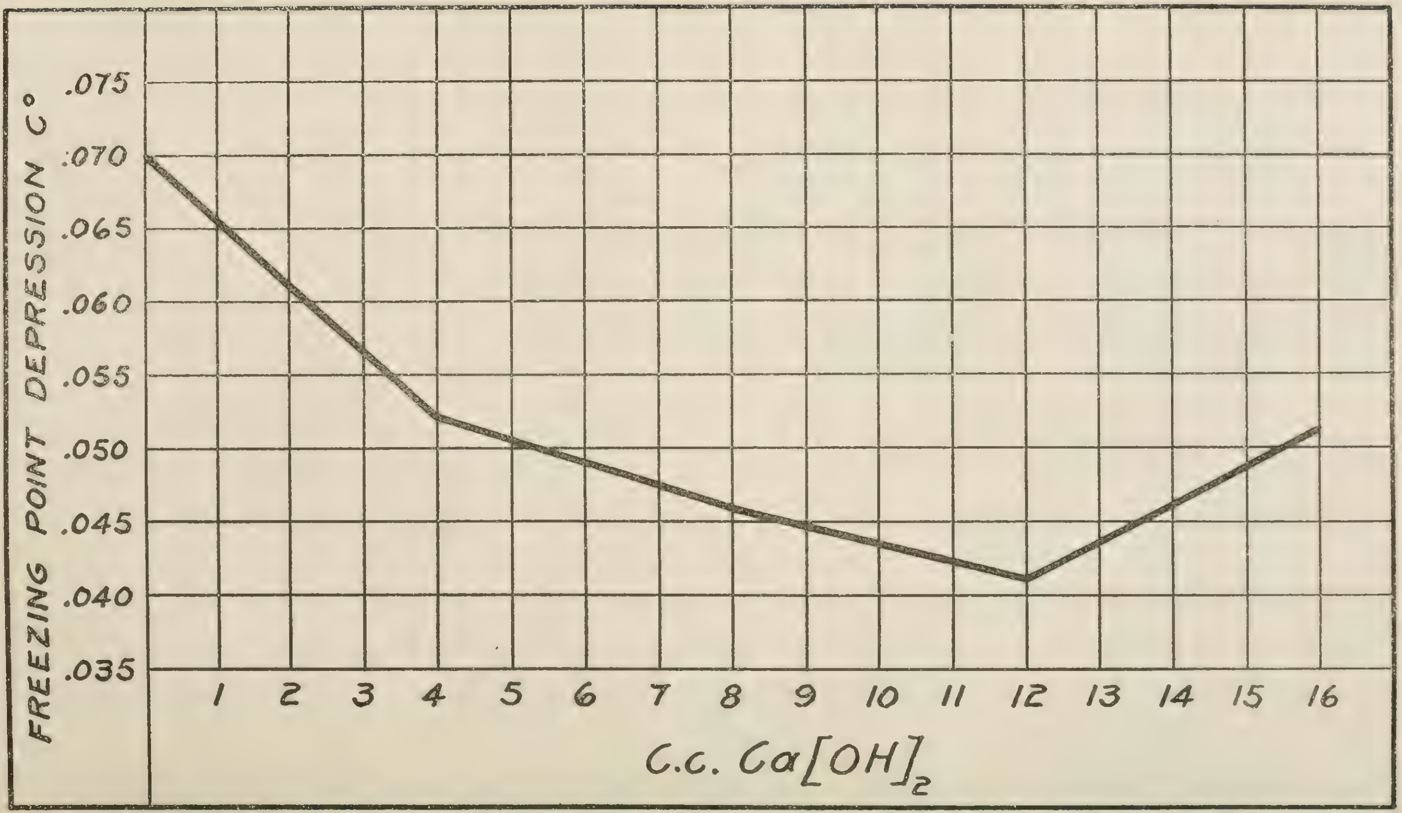

FIGURE 7a. Curve showing the decrease in the depression of soil, which was previously treated with $NaNO_3$, by the addition of $Ca(OH)_2$ down to a certain point and then the increase with the further addition of $Ca(OH)_2$

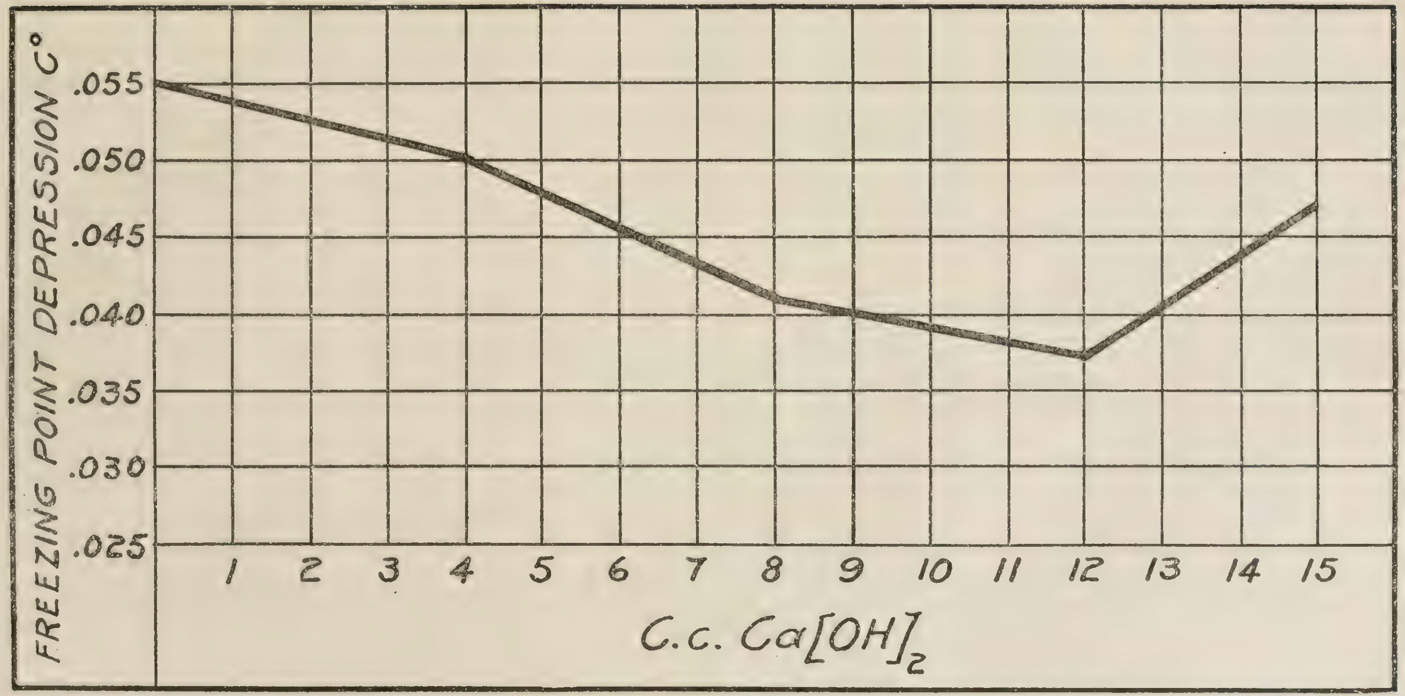

FIGURE 7b. Curve showing the decrease of the depression of soil, which was previously treated with $CaNO_3$, by the addition of $Ca(OH)_2$ down to a certain point and then the increase with the further addition of $Ca(OH)_2$

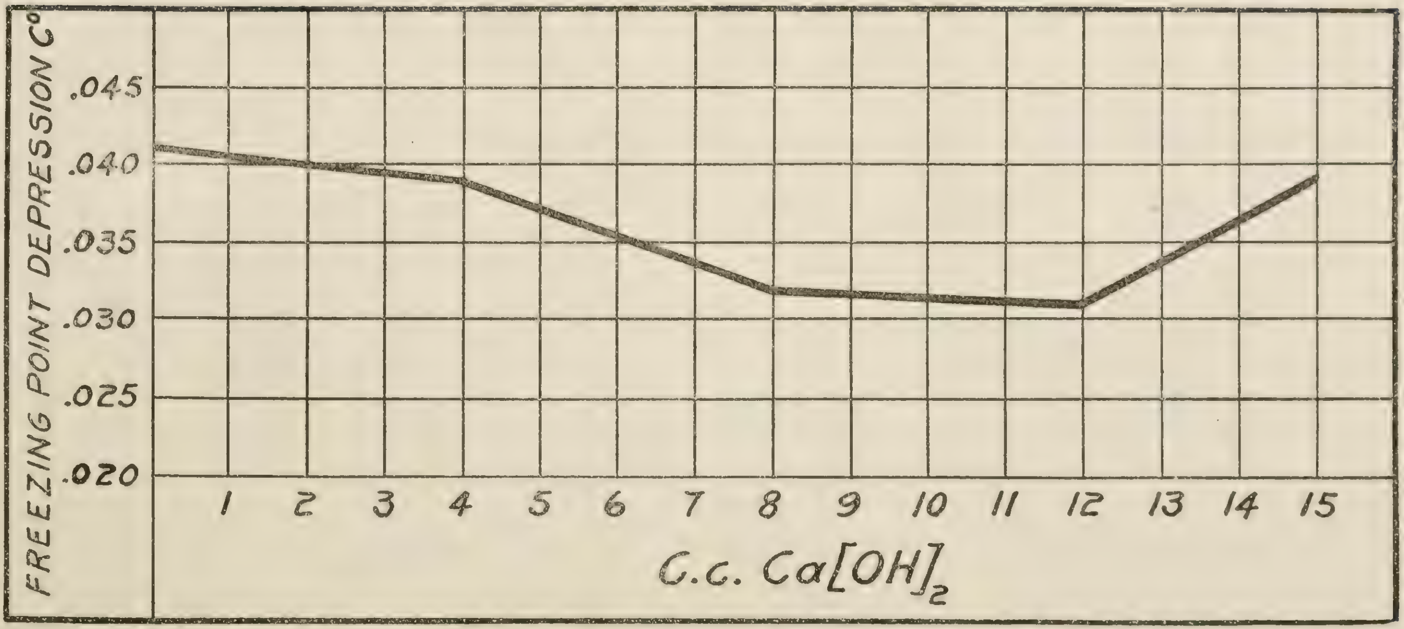

FIGURE 7c. Curve showing the decrease in the depression of soil, which was previously treated with K_2SO_4, by the addition of $Ca(OH)_2$ down to a certain point and then the increase with the further addition of $Ca(OH)_2$

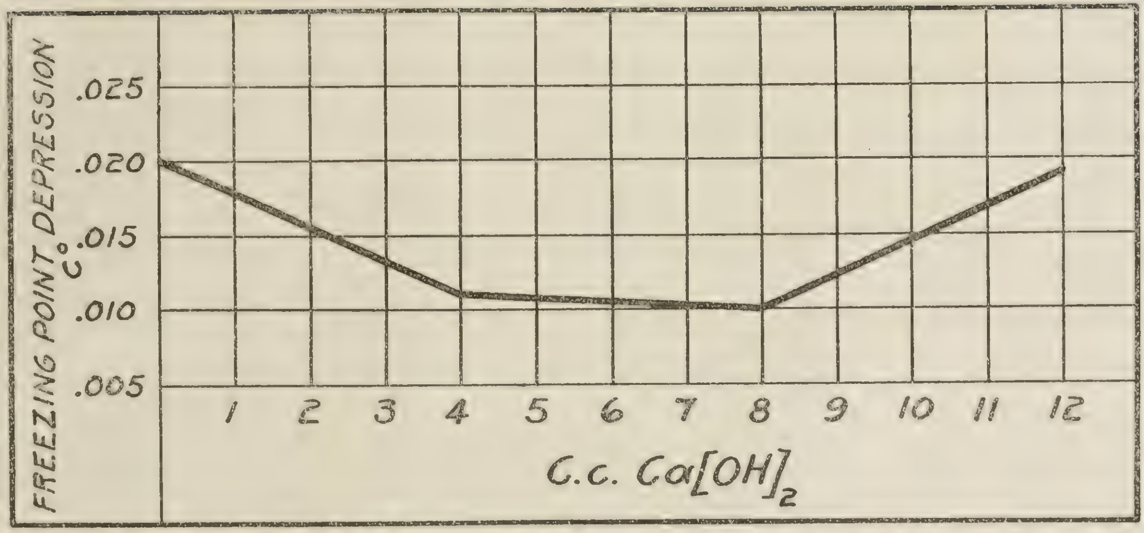

FIGURE 7d. Curve showing the decrease in the depression of soil which was previously treated with $CaH_4(PO_4)_2$, by the addition of $Ca(OH)_2$ down to a certain point and then the increase with the further addition of $Ca(OH)$

TABLE 13. FREEZING POINT DEPRESSION OF SOILS WHICH WERE TREATED WITH SALT SOLUTIONS AND TITRATED WITH $Ca(OH)_2$.

Reagents.		Depression.
2 gm. soil plus 2 c.c. N/10 $NaNO_3$ plus 10 c.c. water		.070°C
	plus 4 c.c. $Ca(OH)_2$	.052
	plus 4 c.c. $Ca(OH)_2$	.046
	plus 4 c.c. $Ca(OH)_2$	.041
	plus 4 c.c. $Ca(OH)_2$	.051
2 gm. soil plus 2 c.c. n/10 $CaNO_3$ plus 10 c.c. water		.056°C
	plus 4 c.c. $Ca(OH)_2$	.050
	plus 4 c.c. $Ca(OH)_2$	.041
	plus 4 c.c. $Ca(OH)_2$	.037
	plus 3 c.c. $Ca(OH)_2$	.047
2 gm. soil plus 2 c.c. n/10 K_2SO_4 plus 10 c.c. water		.041°C
	plus 4 c.c. $Ca(OH)_2$	.039
	plus 4 c.c. $Ca(OH)_2$	.032
	plus 4 c.c. $Ca(OH)_2$	.031
	plus 3 c.c. $Ca(OH)_2$	.039
2 gm. soil plus 2 c.c. n/10 $CaHPO_4$ plus 10 c.c. water		.020°C
	plus 4 c.c. $Ca(OH)_2$	.011
	plus 4 c.c. $Ca(OH)_2$	.010
	plus 4 c.c. $Ca(OH)_2$	.019

It is at once seen that the general type of numerical data and curve yielded by the soils which were treated with soluble salts is almost exactly the same as that obtained when a pure acid or acid salt or a soil treated with an acid or acid salt is titrated with $Ca(OH)_2$. The irresistable and logical conclusion immediately appears to be, therefore, that the substance produced in the soils when they are treated with different soluble salts, consists either of a soluble free acid or an acid salt. This conclusion appears to be supported by what is already known concerning the reaction between a salt solution and the soil. According to the adsorption and chemical theories, when a soil reacts with a salt, the base of the salt is taken up by the soil and leaves in solution a free acid, or the base taken up releases a weaker base such as aluminum, which combines with the acid radical of the salt to form an acid salt.

Hence, the answer to the above question, what is the nature of the substance produced in the soil by the application of soluble salts, which increases the lime requirement, *appears to be that it consists either of a free acid or an acid salt, but most likely the latter.*

At this point it should be stated that the above explanation as to the cause of the acid curve, applies only to the neutral salts and not to the acid phosphate salts, $CaH_4(PO_4)_2$ and K_2HPO_4. These phosphate salts are acid salts and will produce the acid curve even before they are applied to the soil. The acid curve produced after they are applied to the soil is doubtless due to the same compounds and not necessarily to some other acid or acid salt formed.

It should also be recorded that the acid curve will be obtained upon the application of soluble salts only when the soil shows a lime requirement, by the freezing point method. If the soil shows no lime requirement, such as the quartz sand, the acid curve will not be obtained, except in the case of the phosphate salts. The same is true when a soil is alkaline or already saturated with a base. If a soil, however, takes up only a very small amount of lime, the acid curve will be very unpronounced.

Not all neutral salts give in the soil an acid curve of the same degree of pronouncement. That is to say the amount of decrease in the depression is not the same for all neutral salts. Thus $Ca(NO_3)_2$, $NaNO_3$,

KNO_3, KCl, and $CaCl_2$ give a far more pronounced acid curve than K_2SO_4, $MgSO_4$, $(NH_4)_2SO_4$, and $NaH_2C_2O_2$. This, however, is naturally to be expected since the products formed by the reaction between the $Ca(OH)_2$ and the acid or acid salt of these neutral salts possess different degrees of dissociation or solubility.

In considering the results on the effect of acids upon the lime requirement of soils, it was seen that when a soil, which showed a large lime requirement was treated with an excess of dilute acid, the supernatant liquid failed to give the acid curve, while the sediment did, but when the sediment was washed, then the acid curve could no longer be obtained. The natural and logical question now rises, do similar phenomena also occur in the case of the salt solutions?

The answer to this question was obtained by attacking the problem in the same manner as before, namely, to several different soils, which showed a high lime requirement, were added different salt solutions in the ratio of 10 grams of soil to 50 c. c. of the solution of N/10 strength. The mixture was stirred thoroughly for a few minutes, then allowed to stand for about an hour until the supernatant liquid became clear. Then some of the supernatant liquid was poured into the freezing tube without filtering, and titrated with $Ca(OH)_2$ in the usual manner. It was found that the depression began to increase immediately upon adding about 2 c. c. of $Ca\ (OH)_2$, indicating that the supernatant liquid failed to give an acid curve. Then the remainder of the solution was poured out and the sediment was placed in the freezing tube and titrated with $Ca(OH)_2$. It was found that the freezing point depression decreased with the increased addition of $Ca(OH)_2$ until a certain point was reached and then commenced to rise. The results then plotted into an acid curve, and proved that the soil contained an acid or acid salt or some substance which was not equally or proportionally represented in the supernatant solution. In another sample of soil similarly treated, the sediment was washed with water and then titrated. In this case the freezing point depression remained constant up to a certain point and then began to rise. The results, then plotted into an absorption curve, and proved that the substance which gave the acid curve above was washed away with water.

These experiments were repeated with many of the neutral salts using different soils, and in every case the results were the same, namely the supernatant liquid failed to give an acid curve while the sediment did, but when the sediment was washed then it no longer yielded an acid curve.

These results then agree perfectly with those obtained with acids, and whatever is the explanation for the one case is true also for the other.

Since no mineral soil out of a number of 80 tested for lime requirement in their natural condition gave an acid curve but only an absorption curve, and inasmuch as the free acid and acid salt produced in these soils when they were treated with neutral salts or acids and acid salts, were carried away by washing and the soils then gave an absorption curve, it seems safe and logical to conclude that the presence of soluble acids, or acid salts in the mineral soils under field conditions is only temporary and probably never permanent. The acidity or lime absorption of the mineral soils, therefore, is probably due mainly, if not entirely, to the insoluble acids of the soil, the silicic acid, acid alumino-silicate, and silica, and perhaps to the insoluble organic matter. There is probably then practically no active acidity in the mineral soils, but only negative. Exceptions to this general statement are probably very few.

In the peats and mucks, however, the formation of the organic acids is probably quite rapid, and consequently these soils may contain permanent active acidity, as well as permanent negative acidity.

One more point before concluding. If it is true—which is beyond any doubt—that when a soil is treated with an excess of acid, acid salt and neutral salt, the supernatant liquid contains very little acid or acid salt, while the soil mass itself retains a large amount of the acid or acid salt (or a substance which greatly increases the lime requirement), then the question rises, can any of the present soil acidity methods which employ neutral salts and use only the supernatant liquid, give the true lime requirement of the soil? This is indeed a question of great and fundamental importance and must not be ignored.

NOTE: After the foregoing report was completed and submitted for publication there were received from the Rhode Island Experiment Station samples of twelve different soils, with a request from Mr. F. R. Pember to determine their lime requirement by the freezing point method. As the cultural history of these soils is known, their results on lime requirement are of high interest and great significance from the standpoint of the reliability and value of the freezing point method. The data obtained are detailed in the following table:

TABLE 14. LIME REQUIREMENT OF SOILS.

Number of soil.	Pounds CaO per 2,000,000 pounds soil.
1	10,096.2
2	6,730.8
3	15,705.2
4	27,000
5	15,705.2
6	8,974.4
7	560.9
8	560.9
200	8,413.5
201	8,413.5
202	6,730.8
203	6,730.8

It will be at once seen that the different soils took up entirely different amounts of lime; the quantity ranging from 560.9 pounds CaO per acre in the case of soils No. 7 and 8 to 27,000 pounds in the case of soil No. 4.

Soils No. 7 and 8 are sand, while all the other soils may be classed as very fine sandy loam. Since the texture of the latter soils is more or less the same, their different lime requirement must be due to the difference in the cultural treatment they have received. In other words, the great variation in the lime requirement of these soils, which originally probably belonged to the same series and type, is caused by the different cultural treatment they have received. Indeed, their cultural history, as indicated by the following communication from Mr. Pember, proves such to be the case:

"The soil of samples No. 1 and 3 came from field plat No. 23 in the spring of 1915 and was stored under greenhouse conditions until used.

For full description of the growth of plants in the field on this soil, see Rhode Island Bulletin No. 160. Before growing barley in this soil the past winter, a liberal amount of K N and P was added to the soil. No. 2 received in addition C. P. $CaCO_3$ at the rate of 3 tons per acre, area basis. No. 3 received in addition a solution of H_3PO_4.

Soils No. 4 to 6 came from the benches in the greenhouse where the carnations are growing at the present time. All had received stable manure for the last three years and Nos. 4 and 5 have had the stable manure supplemented with large amounts of chemical manure. Nos. 7 and 8 are sand in which carnations are growing for the third season and the chemical manures added during the three years have exceeded the amount added to Nos. 4 or 5.

Soils No. 200 and 201 came from the vetch-clover area of the corn acre this spring but the samples were taken about four weeks apart. Nos. 202 and 203 came from the fallow area of this same field at the same time as No. 200 and 201. We speak of the "corn acre" because this field has been planted to corn each year for about twenty years. One section of the field has crimson clover and winter vetch sown at the last cultivation of the corn, while on what we term the fallow section, the corn receives clean cultivation throughout the season, and the section remains fallow the rest of the year.

Carnation plants put into Nos. 4 and 5 last fall failed to make much growth, and have done very poorly since early winter in sand No. 8. In No. 2 the growth of the barley was much improved by the addition of $CaCO_3$ while the addition of H_3PO_4 depressed the growth only 19%"

The values of the lime requirement of the different soils as shown in table 14 are of very great significance in the light of the facts contained in the above communication. According to Mr. Pember's letter, for instance, soils No. 1, 2 and 3 came from the same plot and consequently they should be quite uniform texturely. They all received liberal applications of K P and N. Soil No. 2, however, received in addition, 3 tons of $CaCO_3$. This soil, therefore, shows much less lime requirement than soil No. 1 which may be taken as a check. Soil No. 3, received, in addition to K P and N, also a solution of H_3PO_4. This soil shows a far greater lime requirement than the other two soils.

Soils No. 4, 5 and 6 received stable manure, and soils No. 4 and 5 received in addition large amounts of chemical fertilizers. The lime requirement of soils No. 4 and 5 which received the chemical fertilizers is much greater than that of soil No. 6.

Soils No. 7 and 8 are almost quartz sand and although they were treated with large applications of fertilizers, their lime requirement is very small, since quartz sand usually takes up very little, if any, lime.

Soils No. 200 and 203 came from the same field but soils No. 200 and 201 came from the "corn acre" and Nos. 202 and 203 from the fallow area. The former two soils show a greater lime requirement than the two latter soils.

The failure of the carnations to grow in soils No. 4, 5 and 8 is not due entirely to the lack of lime, but to the tremendous concentration of the solution of these soils. These soils have received, evidently, such large applications of chemical manures that the concentration of their solution is really tremendous. Thus, at a very high moisture content, almost at the point of saturation, these soils gave a depression of over

.600° C., which is about 30 times as great as that of normal soils. At a lower moisture content this depression would be much greater. Now, when it is considered that the depression of the cell sap of young cereal plants amounts to a little less than 1.00° C., it becomes at once evident that the failure of the carnations to grow in these soils is undoubtedly due to the great concentration of the soil solution.

The results on the lime requirement of these Rhode Island soils seem to afford a most excellent confirmation of the previous laboratory results and a definite proof that the lime requirement value, as indicated by the freezing point method, is due to a definite factor and this factor seems to be somewhat related to crop growth.

SUMMARY.

In the present paper there is presented the freezing point method as a new method for determining the lime requirement of the soils and possibly the nature of their acidity.

The method consists of adding to 2 grams of soil 10 c. c. of water and determining the lowering of the freezing point. Then to this mixture are added various amounts of $Ca(OH)_2$ until there occurs a change in the magnitude or direction of the freezing point depression.

The method is based upon the following principles for indicating the lime requirement of soils and the nature of their acidity: (1) If a soil contains a free soluble acid or acid salt its freezing point depression decreases upon adding to it various quantities of $Ca(OH)_2$ until a certain point is reached and then it begins to increase with further addition of $Ca(OH)_2$. This point is considered to be the point of neutralization of the acid or acid salt and of the saturization of the soil for lime. The results plot into a type of curve which is designated as an acid curve. (2) If a soil, however, contains neither a soluble acid nor an acid salt but possesses an absorptive power for lime, due probably to the unsatisfied silicate compounds and organic matter, the freezing point depression remains constant as more and more of $Ca(OH)_2$ is added to the soil until a critical point is reached and then it commences to rise with further addition of $Ca(OH)_2$. The critical point is considered to be the saturation of the soil for lime. The results plot into a type of curve which is designated as an absorption curve. (3) If the soil contains neither a free soluble acid or acid salt, nor an absorptive power for lime, i. e., it is already alkaline and saturated with bases, then the freezing point depression starts to rise almost immediately upon the addition of a small amount of $Ca(OH)_2$. The curve obtained from these results is named the alkaline or no-lime-absorption curve.

The method is simple, accurate, extremely rapid, entirely different in principle from that of any other method now in vogue, and appears to be very promising as it affords a direct means of studying the problem of soil acidity.

The lime requirement of over 95 different soils in their natural state was determined by this method. The results show that the amount of lime taken up by these soils varies greatly.

The freezing point method gives much higher lime requirement than the Veitch method. It appears that the former method probably gives the true maximum lime requirement of soils. By true maximum lime requirement is meant the total amount of lime required to neutralize any soluble acids and acid salts of soils and to satisfy their absorption-adsorption properties for lime.

All the mineral soils tested gave an absorption curve, indicating probably that they did not contain a soluble acid or acid salt.

The absorption curve of the mineral soils signifies that the $Ca(OH)_2$ is taken out of solution and is rendered inactive as far as the freezing point depression is concerned. The substances which accomplish this are in the solid phase. A critical consideration of the soil mass as well as many experimental evidences seem to indicate that these solid substances, in the case of the mineral soils, consist mainly of unsaturated silicic acid, silica, acid alumino-silicates, and perhaps insoluble organic matter, probably in the colloidal, hydrated form.

The absorption curve also indicates that there is no basic exchange in soils, when a hydrate is employed, until the soil is satisfied or saturated with the base.

Only a few peats were tested and most of them gave an acid curve, indicating probably that most of them contained free acids.

The same kind of soils took up $Ca(OH)_2$, KOH, NaOH, and NH_4OH in non-chemically equivalent amounts. As a very general rule each soil tended to show a specific reactivity for these different hydrates. This unequal absorption does not appear to be against the value of the freezing point method.

When a soil was satisfied with one base it took up very little if any of another base, or if it did, it released a corresponding amount of the one with which it was already saturated.

On the other hand, when a soil was only partly satisfied with one base it absorbed a corresponding quantity of another.

The addition of acids and acid salts increased the lime requirement of soils. The magnitude of the increase was approximately equal to the amount of lime required to neutralize the quantity of the acid or acid salt added. The results plotted into an acid curve.

When a soil was treated with an excess of acid and then washed, the lime requirement was also increased, but the results plotted into an absorption curve.

When a soil, which showed a high lime requirement, was treated with an excess of acid, the clear supernatant liquid failed to give an acid curve, indicating that it contained very little if any acid. The litmus paper test showed that it was very nearly neutral. The sediment, however, gave an acid curve, signifying that it contained a considerable amount of acid. It turned the blue litmus paper red. When this sediment was washed with water, however, the acid curve could no longer be obtained, showing that the acid was washed away.

All soluble salts increased the lime requirement of soils, but the magnitude of increase was greater in the case of the neutral salts than of the acid phosphate salts. All of the former salts employed augmented the lime absorption of any one soil to the same degree. The same was true of all the latter salts. The increase, however, in both cases was only temporary, as after washing with water the soils possessed the same lime requirement as before treatment. Before washing, the soils gave the acid curve with all the salts, but after washing they all yielded the absorption curve, proving that the substance which caused an increase in the lime requirement and produced the acid curve, was washed away.

The same phenomenon was observed in the case of the salt solutions, as in the acids, namely, when a soil which showed a high lime requirement was treated with an excess of salt solution, the supernatant liquid failed to give an acid curve but the sediment did, but when the sediment was washed with water, then it no longer gave the acid curve, but the absorption curve. These phenomena are very remarkable and exceedingly significant.

Since no mineral soil out of a great number tested gave an acid curve but only an absorption curve, and inasmuch as the free acid, and acid salt produced in these soils when they were treated with neutral salts, or acid and acid salts, were carried away by washing and the soils then gave an absorption curve, the conclusion seems to be that the presence of soluble acids, or acid salts, in the mineral soils under favorable natural conditions is only temporary, if ever present, and never permanent. The acidity or lime requirement of soils, therefore, seems to be due mainly to the insoluble acids of the soil, the silicic acid, silica, acid alumino-silicates, and perhaps to the insoluble organic matter. There appears to be then practically no active acidity in the mineral soils, but only negative. Exceptions to these general statements are probably very few.

In the peats and mucks, however, the formation of organic acids is probably quite rapid, and consequently these soils, as indicated by the data, may contain permanent active acidity as well as permanent negative acidity.

MICHIGAN STATE AGRICULTURAL SOCIETY

ANNUAL REPORT

AND

AUDIT AND EXAMINATION

FOR THE YEAR ENDING DECEMBER 7, 1915

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N. P. HULL, Vice-President

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Custodian of Funds

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(Terms Expire January, 1917)

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Detroit, Michigan

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REPORT OF SECRETARY-MANAGER.

To the Members of the Executive Committee:

The 1915 State Fair was successful from a financial standpoint, notwithstanding the weather conditions were very unfavorable, leaving us a sufficient amount to pay all our necessary expenses for the year and to care for the bonds and interest falling due May 1st, 1916.

The total receipts amounted to $144,978.49 and the total expenses for the year amounted to $130,380.23, showing net receipts of the year's business of $14,598.26. The difference in receipts and expenditures over 1914 was due largely to the fact that in 1914 the purses paid for the Grand Circuit race meet amounted to $37,715, while in 1915 we paid $7,670. It is my opinion that we should continue in the Short Ship circuit, as it took all the receipts, including the Grand Stand, to pay the purses in 1914, while in 1915 the total receipts, including the Grand Stand were between $7,000 and $8,000 more than the amount expended. The total premiums awarded and paid amounted to $26,844.33, which includes badges and cups for champion prizes.

There were 136 Membership tickets sold and 1,261 $2.00 and 50c Exhibitor's tickets. The receipts from stall pens and poultry fees amounted to $1,653. The Auditor's report for the year included herewith gives a summary of receipts and expenses in all Departments.

Appropriation:

Regarding the recommendation made at the last Annual Meeting asking that a Committee be appointed to take up the question of an appropriation at the next legislature, I wish to report that I immediately went to work on the matter with the result that we secured an appropriation of $50,000 per year for the years 1915 and 1916 to be distributed to Michigan Fairs, the Michigan State Fair receiving $16,000 as their portion for 1915, which has been received and used for the payment of premiums.

The appropriation also carried with it the appointment of a Commission, known as the Michigan Agricultural Fair Commission, with the following members:

Michigan Agricultural College, Robert D. Graham, Grand Rapids.
Ancient Order of Gleaners, Grant Slocum, Detroit.
Michigan Farmers' Clubs, Alfred Allen, Mason.
Michigan State Agricultural Society, G. W. Dickinson, Detroit.
Michigan State Grange, John C. Ketchum, Hastings.
Western Michigan Fair, Joseph H. Brewer, Grand Rapids.

The $50,000 appropriated by the legislature was, in my judgment, and I think in the judgment of the other Fair Secretaries, apportioned in an equitable manner and I feel certain if the matter is properly handled, we should experience no difficulty at the next session in securing a continuous appropriation of this amount, or even greater.

$60,000 Bonds:

With reference to the recommendation of your Secretary at the last annual meeting, that we make a second mortgage bond issue of $60,000 to cover the floating indebtedness, I wish to report that the bonds were issued in accordance with such recommendation and sold to the Dime Savings Bank at one per cent discount. This money was used for the payment of floating indebtedness, making a total bond issue of $250,000, $5,000 of which was paid last May, making outstanding bonds unpaid at this date of $245,000. There will fall due May 1st, 1916, bonds to the amount of $10,000, and the interest amounting to $7,350.

There are also bonds of $10,000 due in 1917, 1918 and 1919, and $205,000 May 1st, 1920. I take pleasure in reporting to you that this Society at the present time, has no floating indebtedness, and it will not be necessary to borrow any money this year.

Insurance:

The buildings have been insured this year at a cost of $1,952.38, which is a reduction over 1914 of $297.62, with practically the same amount of insurance carried. We also carry Employes' Liability Insurance with the Casualty Company of America, at a cost of $82.40.

Automobile Races:

On Decoration Day and the day following, May 30th and 31st, I arranged for Automobile Races. The net receipts to this Society from these races amounted to $2,430.85.

On Sunday, October 17th, I arranged for Ford Auto Races, the net receipts from which amounted to $1,436.12.

The Interstate Racing Association of Toledo, Ohio, leased the track for Motorcycle Races on Sunday, June 13th, 1915, for which they paid $500. I again rented the track to the same Association for Motorcycle races on Sunday, September 19th, 1915, for $300, as it was very evident that the Racing Association lost money at the first meet. The total net receipts for the four meets amounted to $4,666.97, a detailed statement of which is included in the Auditor's report.

Our Society saved on account of securing their sanctions from the International Motor Contest Association, the new racing association, rather than from the American Automobile Association, which black-listed us in 1914, $250.00 on the five days auto races. We also had automobile races two days and nights the last week of the Fair, which brought out large crowds and paid us well.

Buildings:

The rental of buildings for storage purposes in 1915 amounted to $2,724.55. The total receipts for rental of buildings and race track during the year amounted to $6,994.63, which together with amount received from the automobile races makes a total of $13,766.08, being all the receipts outside of those pertaining to the Fair.

STATE EXHIBITS.

Fish Exhibit:

On August 4th, a meeting was called with the Michigan State Fish Commission for the purpose of securing an exhibit at the 1915 Fair, and after considerable discussion the Commission unanimously decided to make an exhibit. The same was placed under the Grand Stand and I believe the number of people who visited it and the interest manifested that it was a splendid attraction and a great benefit to the Fair, the Fish Commission and the fish industry generally, as it enabled the people about the State to see the different varieties which inhabit Michigan waters.

Jackson Prison Exhibit:

On July 10th I took up the question with Warden Simpson of the Michigan State Prison at Jackson, of making an exhibit at the Fair and found him ready and willing to co-operate with us. As we had no place inside to conveniently locate this exhibit, it was decided to use a tent, which was placed north of the Horticultural Building where all Fair visitors were enabled to see the products of one of Michigan's State Prisons, which proved very interesting.

Dairy and Food:

The Dairy and Food Department gave us an exhibit in the Dairy Building, which was very creditable.

Michigan Agricultural College:

Some branches of the Michigan Agricultural College were also on exhibition, but it is hoped that we will be favored with a more interesting exhibit from the M. A. C. at the 1916 Fair.

DEPARTMENTAL EXHIBITS.

Horses:

The Horse Department exceeded any Horse Show I think we have ever had and was enjoyed by all.

Cattle:

The Cattle exhibit was light, although about as many breeds were shown as usual. The decrease in number of exhibitors was due largely to the hoof and mouth disease.

Sheep and Swine:

The Sheep exhibit was in excess of 1914, while the Swine exhibit was about equal to last year.

Poultry:

The Poultry exhibit was far in excess of last year.

Farm Products:

The exhibits in this Department fell off slightly over 1914, but the show was one of the best ever held in the building.

Machinery, Implements and Vehicles:

The Machinery exhibit was very interesting this year, although our Machinery Field was covered with water and needs draining. The tractor exhibits were of more interest than heretofore and I believe can be made a great drawing card for the 1916 Fair.

Fruits, Plants and Flowers:

The exhibits in these departments fell off slightly in number over 1914, but in quality were far superior to any we have ever had.

Dairy, Domestic and Apiary:

The Dairy, Domestic and Apiary exhibits showed a splendid increase over last year and every foot of exhibit space in the building was taken.

Needlework, Handicraft and Fine Arts:

I am pleased to make mention of the improvement made in the Needlework Department, which was conceded by all to be the best exhibit we have ever held.

The Handicrafts and Fine Arts Department is also worthy of mention; a suitable building should be provided for this department, which would be the means of bringing us an interesting exhibit, which would be appreciated by many of our visitors.

Educational Department:

Exhibits in this Department fell off slightly in number, but the quality of the exhibit was good.

Boys' State Fair School:

The Boys' State Fair School was of usual interest and although expensive, it assists us quite materially in advertising the Fair throughout the State.

Better Babies' Contest:

The Better Babies' Contest exceeded the 1914 exhibit, having 108 contestants against 35 last year.

SUMMARY OF AMOUNTS OF PREMIUMS OFFERED AND PAID

Departments	Premium Cups Ribbons and Purses Offered Mich.	Others	Total Offered	Amt. Paid.
Horses:				
Breeding Classes	$3,684 00	$225 00	$3,909 00	$2,312 00
Evening Show	4,415 00	....	4,415 00	4,305 00
Cattle	7,559 00	788 00	8,347 00	4,522 00
Sheep	3,330 00	140 00	3,470 00	2,908 00
Swine	2,836 00	225 00	3,061 00	1,673 00
Poultry	2,206 00	....	2,206 00	1,721 00
Agricultural and Horticultural	4,351 50	50 00	4,401 50	3,324 75
Plants and Flowers	857 00	....	857 00	585 00
Dairy, Domestic, Apiary	1,147 25	....	1,147 25	904 44
Needlework, Handicraft and Fine Arts	1,155 50	....	1,155 50	467 50
Educational	1,307 75	....	1,307 75	793 00
Better Babies Contest	168 00	....	168 00	119 00
Total Cost Premiums	$33,017 00	$1,428 00	$34,445 00	$23,634 69
20% to Mich. Exhibitors	....	....	....	1,630 65
Ribbons	330 93	....	330 93	330 93
Cups	817 50	....	817 50	746 50
	$34,165 43	$1,428 00	$35,593 43	$26,342 77
Speed Department	13,200 00	....	13,200 00	7,670 00
	$47,365 43	$1,428 00	$48,793 43	$34,012 77

HORSE DEPARTMENT

Amount of Premiums Offered and Paid

Breeding Classes

Classes	No. Entries Mich.	Others	Premiums Offered Mich.	Others	Total Offered	Amount Paid
Standard Bred	24	4	$451 00	......	$451 00	$212 00
Hackney—German and French Coach	26	8	436 00	......	436 00	291 00
Percheron	18	55	473 00	......	473 00	273 00
Clydesdale	33	....	473 00	......	473 00	350 00
English Shire	1	2	473 00	......	473 00	35 00
Belgian	60	57	436 00	225 00	661 00	392 00
Suffolk	No entries					
Welsh Ponies	1	11	180 00	......	180 00	110 00
Shetland Ponies	22	15	172 00	......	172 00	146 00
Heavy Draft Mares and Geldings	52	....	350 00	......	350 00	263 00
Heavy Delivery	9	....	190 00	......	190 00	190 00
Largest number Draft Horses exhibited by any one exhibitor	18	....	50 00	......	50 00	50 00
Forward to evening show	264	152	$3,684 00	$225 00	$3,909 00	$2,312 00

HORSE DEPARTMENT

Amount of Premiums Offered and Paid

Evening Horse Show

Classes	No. Entries Mich.	Others	Premiums Offered Mich.	Others	Total Offered	Amount Paid
Roadsters	17	8	$380 00	......	$380 00	$315 00
Runabout Class	17	9	190 00	......	190 00	190 00
Harness	30	18	800 00	......	800 00	765 00
Gig	7	3	100 00	......	100 00	100 00
Ladies' Class	11	12	270 00	......	270 00	270 00
Four-In-Hand and Tandems	5	6	260 00	......	260 00	260 00
Championship Harness Class	....	....	50 00	......	50 00	50 00
Saddle Horses	48	38	855 00	......	855 00	845 00
Shetland Ponies	22	8	225 00	......	225 00	225 00
Welsh Ponies	3	5	105 00	......	105 00	105 00

Classes	No. Entries Mich.	No. Entries Others	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Ponies other than Shetlands to Harness	8	11	230 00	......	230 00	230 00
Hunters and Jumpers	50	43	750 00	......	750 00	750 00
Mounted Police	....	....	200 00	......	200 00	200 00
Evening Horse Show Total	218	161	$4,415 00	$.....	$4,415 00	$4,305 00
Day Horse Show Total	264	152	3,684 00	225 00	3,909 00	2,312 00
20% to Mich. Exhibitors	....	....	....	......	....	287 00
Ribbons	....	....	....	......	....	53 62
Silver Cups	....	....	....	......	....	168 00
Grand Total	482	313	$8,099 00	$225 00	$8,324 00	$7,125 82

SPEED DEPARTMENT

Statement of Racing, Michigan State Fair, 1915

No. of Entries	No. of Entries	Class Trotting	Amt. of Purse Offered	Amt. Paid	Amt. Entry Fee Collected	Amt. Entry Fee Refunded	Net Cost
22	7	2:24	$1,000 00	$800 00	$300 00	$........	$500 00
17	8	2:18	1,000 00	800 00	310 00	....	490 00
15	12	2:14	1,000 00	800 00	350 00	....	450 00
23	15	2:30	600 00	360 00	....	....	360 00
18	11	2:20	600 00	360 00	....	....	360 00
8	Declared off	2:13	600 00	....	....	....	....
31	20	2:22	600 00	360 00	....	....	360 00
16	10	2:16	600 00	360 00	....	....	360 00
9	7	2:20 3 years old	600 00	350 00	....	....	350 00
		Pacing					
16	6	2:24	1,000 00	800 00	280 00	....	520 00
18	9	2:17	1,000 00	800 00	380 00	....	420 00
12	6	2:12	1,000 00	800 00	160 00	....	640 00
24	11	2:20	600 00	360 00	....	....	360 00
10	Declared off	2:10	600 00	....	....	....	....
27	17	2:30	600 00	360 00	....	....	360 00
17	Declared off	2:14	600 00	....	....	....	....
25	10	2:16	600 00	360 00	....	....	360 00
4	Declared off	Free for all	600 00	....	....	....	....
312	149		$13,200 00	$7,670 00	$1,780 00	....	$5,890 00

Final Summary:

	1915	1914
Total amount offered in premiums	$13,200 00	$51,600 00
Total amount paid out in winnings	7,670 00	37,715 00
Total amount entry fees collected	1,780 00	21,985 00
Total cost of races	5,890 00	15,730 00

CATTLE DEPARTMENT

Amount of Premiums Offered and Paid

Classes	No. Entries Mich.	No. Entries Others	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Shorthorns	64	54	$682 00	$341 00	$1,023 00	$843 00
Polled Durham	34	27	671 00	......	671 00	402 00
Hereford	55	37	671 00	200 00	871 00	478 00
Aberdeen Angus	64	39	671 00	147 00	818 00	590 00
Galloway	....	37	663 00	......	663 00	256 00
Red Polled	23	19	671 00	......	671 00	380 00
Jersey	45	....	670 00	75 00	745 00	464 00
Guernsey	28	....	670 00	......	670 00	193 00
Holstein-Friesian	31	....	671 00	......	671 00	377 00
Ayrshire	20	....	658 00	......	658 00	117 00
Brown Swiss	....	24	606 00	25 00	631 00	214 00
Dairy Cows—All Breeds	7	1	100 00	......	100 00	100 00
Fat Steers	6	2	125 00	......	125 00	78 00
Herdsman Special	5	....	30 00	......	30 00	30 00
Totals	382	240	$7,559 00	$788 00	$8,347 00	$4,522 00
20% to Mich. Exhibitors	....	....	....	......	....	657 20
Ribbons	....	....	....	......	....	42 02
Silver Cups	....	....	....	......	....	189 00
Grand Total	....	....	....	......	....	$5,410 22

SHEEP DEPARTMENT

Amount of Premiums Offered and Paid

Classes	Mich. No. Entries	Others No. Entries	Mich. Premiums	Others Offered	Total Offered	Amount Paid
Shropshire	89	....	$270 00	$80 00	$350 00	$270 00
Hampshire	53	15	270 00	30 00	300 00	262 00
Oxford Downs	39	21	270 00	......	270 00	204 00
South Downs	28	28	270 00	......	270 00	233 00
Horned Dorsets	30	41	270 00	......	270 00	262 00
Cheviots	29	50	270 00	......	270 00	264 00
Cotswold	16	22	270 00	15 00	285 00	218 00
Leicester	17	....	270 00	......	270 00	100 00
Lincoln	35	22	270 00	......	270 00	226 00
Delaine Merino	74	30	270 00	......	270 00	268 00
American Merino	64	36	270 00	......	270 00	268 00
Rambouillet	68	16	270 00	......	270 00	259 00
Fat Sheep	32	1	90 00	15 00	105 00	74 00
Total	574	282	$3,330 00	$140 00	$3,470 00	$2,908 00
20% to Mich. Exhibitors	....	....	....	......	....	296 60
Ribbons	....	....	....	......	....	57 80
Silver Cups	....	....	....	......	....	237 50
Grand Total	....	....	....	......	....	$3,499 90

SWINE DEPARTMENT

Amount of Premiums Offered and Paid

Classes	No. Entries Mich.	No. Entries Others	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Berkshire	60	35	$322 00	$42 00	$364 00	$319 00
Poland China	39	38	352 00	......	352 00	233 00
Hampshire	28	30	352 00	......	352 00	314 00
Victoria and Small Yorkshire	30	....	352 00	......	352 00	195 00
Chester White	24	7	352 00	......	352 00	132 00
Large Yorkshire	No Entries		352 00	15 00	367 00	No Entr's
Duroc Jersey	89	21	352 00	168 00	520 00	326 00
Tamworth	21	27	352 00	......	352 00	122 00
Fat Hogs	5	......	50 00	......	50 00	32 00
Total	296	158	$2,836 00	$225 00	$3,061 00	$1,673 00
20% to Mich. Exhibitors	....	....	....	......	....	239 60
Ribbons	....	....	....	......	....	30 76
Silver Cups	....	....	....	......	....	152 00
Grand Total	....	....	....	......	....	$2,095 36

POULTRY DEPARTMENT

Amount of Premiums Offered and Paid

Classes	No. Entries	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Poultry	1308	$1,164 00	....	$1,164 00	$968 50
Bantams	422	396 00	....	396 00	279 00
Turkeys, Ducks and Geese	376	336 00	....	336 00	269 50
Pigeons	149	205 00	....	205 00	152 00
Hares	110	105 00	....	105 00	52 00
Total	2365	$2,206 00	....	$2,206 00	$1,721 00
Ribbons	....	....	....	....	148 15
Grand Total	....	....	....	....	$1,869 15

PLANTS AND FLOWERS

Amount of Premiums Offered and Paid

Classes	No. Entries	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Plants in Pots	12	$290 00	....	$290 00	$110 00
Plants in Boxes and Baskets	11	57 00	....	57 00	25 00
Cut Flowers	16	420 00	....	420 00	420 00
Floral Designs	2	75 00	....	75 00	25 00
Bridal Bouquet	2	15 00	....	15 00	5 00
Grand Total	43	$857 00	....	$857 00	$585 00

DAIRY, DOMESTIC AND APIARY

Amount of Premiums Offered and Paid

Classes	No. Entries	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Butter, Cheese, Milk, Cream	16	$686 00	....	$686 00	$485 44
Milking Contest	4	32 50	....	32 50	32 50
Bread, Cake and Pies	97	108 00	....	108 00	103 50
Canned Fruits and Vegetables	48	42 00	....	42 00	41 25
Preserves, Jam, Jellies and Pickles	144	129 25	....	129 25	117 25
Wines	20	17 50	....	17 50	16 50
Apiary	39	132 00	....	132 00	108 00
	368	$1,147 25	....	$1,147 25	$904 44

AGRICULTURAL AND HORTICULTURAL

Amount of Premiums Offered and Paid

Classes	No. Entries	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Grain and Seeds	255	$660 00	....	$660 00	$582 00
Forage Plants	26	153 00	....	153 00	147 00
Roots and Vegetables	292	1,322 25	....	1,322 25	889 25
Fruits	804	2,216 25	50 00	2,266 25	1,706 50
	1377	$4,351 50	$50 00	$4,401 50	$3,324 75
20% to Mich Exhibitors (Fruit only)	....	....	....	....	150 05
Grand Total	1377	$4,351 50	$50 00	$4,401 50	$3,474 80

NEEDLEWORK, HANDICRAFT AND FINE ARTS

Amount of Premiums Offered and Paid

Classes	No. Entries	Premiums Offered Mich.	Premiums Offered Others	Total Offered	Amount Paid
Needlework	827	$845 50	....	$845 50	$210 50
Handicraft and Fine Arts	171	310 00	....	310 00	257 00
Grand Total	998	$1,155 50	....	$1,155 50	$467 50

EDUCATIONAL—INCLUDING BOYS' STATE FAIR SCHOOL

Amount of Premiums Offered and Paid

Classes	No. Entries	Premiums Offered		Total Offered	Amount Paid
		Mich.	Others		
County Normal	70	$78 75	....	$78 75	$54 00
High Schools	92	109 25	....	109 25	75 50
Grammar Grades	162	182 75	....	182 75	129 00
Intermediate Grades	176	198 00	....	198 00	143 25
Primary Grades	64	77 25	....	77 25	66 25
Kindergarten	18	20 25	....	20 25	15 75
Manual Training	238	275 25	....	275 25	175 00
Village Schools	180	172 50	....	172 50	92 25
District Schools	269	193 75	....	193 75	42 00
Grand Total	1269	$1,307 75	....	$1,307 75	$793 00

BETTER BABIES CONTEST

Amount of Premiums Offered and Paid

Classes	No. Entries	Premiums Offered		Total Offered	Amount Paid
		Mich.	Others		
Babies from rural districts and towns of 1,000 population or less	26	$40 00	....	$40 00	$33 00
Babies from cities and towns of over 1,000 and less than 10,000 population	34	40 00	....	40 00	21 00
Babies from cities of over 10,000 population	46	40 00	....	40 00	40 00
Triplets, 6 mos. and under 24 mos.	1	30 00	....	30 00	15 00
Twins, 6 mos. and under 24 mos.	1	18 00	....	18 00	10 00
	108	$168 00	....	$168 00	$119 00

AUDIT AND EXAMINATION.

December 4, 1915.

Michigan State Agricultural Society, Detroit, Michigan:

Dear Sirs:—Pursuant to your request, we have made an audit of your books and records for the period from December 1, 1914, to November 30, 1915. We herewith submit our report together with the following Exhibits and their supporting Schedules:

Exhibit "A" Balance Sheet.
Exhibit "B" Statement of Revenues and Expenses.
Exhibit "C" Statement of Surplus Account.

Receipts:

All reported cash receipts have been properly credited and accounted for.

Disbursements:

All disbursements were made by checks on bank, and are supported by properly authenticated vouchers.

Cash:

The cash on hand, as at November 30, 1915, was found correct as shown in the balance sheet.

Bank:

The bank account was reconciled with statements furnished by the bank. All checks paid and returned by bank were carefully scrutinized and were found to be regularly issued for the purposes intended.

Accounts Receivable:

Some of the old accounts receivable are considered uncollectible, and we recommend that a sufficient reserve to offset the amount of probable losses in the collection of accounts receivable be set up on your ledger by transferring the amount from surplus account.

Fixed Assets:

The values of fixed assets are shown in the balance sheet, as exhibited by the books, and are subject to revaluation by appraisal.

Liabilities:

The liabilities, as shown herein, represent all those ascertainable, and, in our opinion, are substantially correct.

General Comment:

As requested by your Mr. Dickinson, we have reclassified some of the expense accounts in order to more clearly apply expenses to the departments affected.

While this results in a more comprehensive report, yet comparisons between this year's operations with those of former years, may, in some instances, be found difficult.

The scope of our work performed in addition to the usual duties incident to auditing the books, covered the clerical work of keeping the general books, inspection of the sales of tickets, admissions to the grounds, side-show commissions, verification of space allotted to exhibitors, etc., etc., also audits of receipts and disbursements pertaining to various other attractions during the year.

We are pleased to state, and without solicitation, that the conduct of the affairs of the Society, which came within our notice, were all conducted in such a manner as to reflect most creditably, in our opinion, upon the management and its entire staff.

Respectfully submitted,
A. W. EHRMAN & CO.,
Public Accountants.

EXHIBIT "A"

BALANCE SHEET

As at November 30, 1915.

ASSETS.

Current:		
Peoples State Bank	$1,501 06	
American Savings Bank	17,350 00	
Accounts Receivable (Schedule "1')	9,714 97	
Contracts Receivable (Schedule "2")	1,177 00	
		$29,743 03
Fixed:		
Land (Schedule "3")	$285,104 92	
Buildings (Schedule "4")	316,210 38	
Electric Plant and Equipment (Schedule "5")	19,902 92	
Office Furniture and Fixtures (Schedule "6")	1,281 49	
Sundry Equipment (Schedule "7")	7,947 94	
		630,447 65
Inventory:		
Lumber and Brick		139 50
Deferred Charges:		
Bond Expenses Prepaid	$775 88	
Advertising Prepaid	30 00	
		805 88
		$661,136 06

LIABILITIES.

Current:		
Sundry Accrued Items	$1,080 00	
Accounts Payable	10 00	
Accrued Interest on Bonds	1,225 00	
		$2,315 00

Deferred Credits:			
Deposits on 1916 Contracts (Schedule "8")		$4,825 00	
Reserve for Lease Race Track		10,310 23	
			$15,135 23
Mortgage Bonds:			
Bonds Outstanding			245,000 00
Surplus (Exhibit "C")	$368,933 07		
Less: Adjustments	845 50		
		$368,087 57	
Special Appropriation by State		16,000 00	
Net Profit December 1, 1914, to November 30, 1915 (Exhibit "B")		14,598 26	
			398,685 83
			$661,136 06

This Balance Sheet, subject to comment contained in the accompanying report, in our opinion, substantially reflects the financial status of the Society as at November 30, 1915.

EXHIBIT "B"

STATEMENT OF REVENUES AND EXPENSES

December 1, 1914, to November 30, 1915.

REVENUES

Admission:		
General Day	$58,586 43	
General Night	2,765 27	
Horse Show	2,257 00	
Speed Department (Grand Stand)	5,629 00	
Automobile Races, Day (Grand Stand)	7,575 75	
Automobile Races, Night (Grand Stand)	2,203 75	
Exhibitors' Tickets	1,236 00	
Membership Tickets	260 00	
Automobile Parking	1,193 60	
		$81,706 80
Concessions and Contracts:		
Midway	$4,091 40	
Main Building Exhibitors	2,855 25	
Main Building Concessions	147 00	
Machinery Building Exhibitors	812 00	
Machinery Field Exhibitors	538 00	
Dairy Building Exhibitors	820 80	
Automobile Building Exhibitors	50 00	
Automobile Show Rental Exhibitors	5,000 00	
Land Show Exhibitors	258 00	
Score Card Privilege	635 00	
Miscellaneous Concessions	16,998 00	
Miscellaneous Exhibitors	1,046 00	
		33,251 45
Sundry:		
Speed Department—Booking Privilege	$5,900 00	
Speed Department—Race Entrance Fees	2,790 00	
Rental of Race Track	4,270 08	
Automobile Races, May 30, 1915	3,263 95	
Dairy Lunch Proceeds	357 58	
Sale of Electric Current to Exhibitors	492 55	
Ford Automobile Races, October 17, 1915	2,707 50	
Cycle Car Races, June 13, 1915	500 00	
Motorcycle Races, September 19, 1915	300 00	
Stall and Pen Fees	1,650 50	
Team Passes	35 00	
Rent Income for Storage of Autos, etc	2,724 55	
Advertising, Premium List	2,916 00	
Advertising, Official Program	1,730 00	
Miscellaneous Revenues	382 53	
		30,020 24
Total Revenues		$144,978 49

EXPENSES

General and Administrative (Schedule "9")	$16,364 89	
General Operating (Schedule "10")	18,657 44	
Advertising (Schedule "11")	16,563 22	
Speed Department (Schedule "12")	12,992 66	
Sundry Department (Schedule "13")	43,713 73	

Ford Automobile Race, October 17, 1915	$1,368 72	
Automobile Races, May 30-31, 1915	833 10	
Free Attractions (not chargeable to other Departments)	4,589 62	
Interest on Notes and Bonds	15,192 93	
Miscellaneous General Expenses	103 92	
Total Expenses		$130,380 23
Profit carried to Surplus Account		$14,598 26

EXHIBIT "C"

SURPLUS ACCOUNT

As at November 30, 1915.

Balance November 30, 1914		$368,933 07	
Add:			
Adjustment of 1913 Profit and Loss		50 00	$368,983 07
Deduct:			
Harold McIntyre Suit 1908 Attractions	$300 00		
Adjustment of 1914 Profit and Loss	225 50		
Adjustment of Bad Debts 1914	370 00		895 50
			$368,087 57
Add:			
Special Appropriation by State of Michigan	$16,000 00		
Net Profit, Dec. 1, 1914, to Nov. 30, 1915.	14,598 26		30,598 26
Surplus as at November 30, 1915			$398,685 83

SCHEDULE "1"—(EXHIBIT "A")

ACCOUNTS RECEIVABLE

As at November 30, 1915.

Race Entrance Fees—1915:		
Bell, Dr. D. C.	$20 00	
Carnathan, Bob	50 00	
Cherry, R. P.	120 00	
Davis, Budd	20 00	
Floyd, C. L.	90 00	
Goldberg, J. E.	40 00	
Gosnell, Curt	40 00	
Graves, Wm.	30 00	
Harrison, W. H.	110 00	
Hayes, T. A.	30 00	
Hooper, J. D.	30 00	
Little, E. R.	60 00	
Loomis, Geo. C.	50 00	
Lyons, W. B.	60 00	
Maley, C. E.	140 00	
Scott, Dr. J. A.	20 00	
Stice, F. S.	55 00	
Valentine, C. A.	104 00	
Wheeler, Geo. W.	50 00	
Woods, J. W.	50 00	
		$1,169 00
Race Entrance Fees—1914:		
Burnett, L. D.	$300 00	
Britt, A. V.	90 00	
Goodison, Edw.	50 00	
Gramlich, Mary L.	30 00	
Held, S. E.	90 00	
Hutton, Geo. E.	50 00	
James, H. H.	165 00	
Morris, R. C.	100 00	
Newby, W. F.	100 00	
Proctor, S. A.	240 00	
Travis, Brook	50 00	
		1,265 00
Race Entrance Fees—1913:		
Gray, J. E.		811 50

Race Entrance Fees—1912:		
Downes, Geo. A.	$150 00	
Finn, Frank M.	30 00	
Gahagen, Joe	390 00	
Long, E. A.	225 00	
Newton, S. M.	250 00	
Shutt, M. D.	600 00	
Winterstein, H. E.	75 00	
		$1,720 00
Race Entrance Fees—1911:		
Hickey, J. C.	$50 00	
Lamar, J. C.	135 00	
Parker, Bascom	500 00	
		685 00
Race Entrance Fees—1910:		
Adams, J. C.	$250 00	
Baum, Geo. W.	70 00	
Carter, D. K.	75 00	
Evans, Dave	250 00	
Ferney, John	50 00	
Fountain Stock Farm	135 00	
Gaith, Geo. W.	150 00	
Hogan, Jas.	250 00	
Jacobs, C. C.	50 00	
Owings, W. A.	115 00	
Rauprich, A.	250 00	
Sheridan, T. D.	250 00	
Stubblefield, W. H., Jr.	110 00	
Teachout, Fred	25 00	
Ward, D. J.	65 00	
		2,095 00
Sundry Accounts:		
Ann Arbor Buggy Co.	$33 75	
Automatic Oil Gas Burner Co.	2 42	
Detroit Driving Club	95 75	
Gray Bros. Electric Co.	32 25	
Mitchell Reo Co.	15 00	
Moone, A. H.	640 00	
Overland—Detroit Co.	60 00	
Packard Motor Co.	1,040 30	
Rocks Automobile School	50 00	
		1,969 47
Total		$9,714 97

SCHEDULE "2"—(EXHIBIT "A")

CONTRACTS RECEIVABLE

November 30, 1915

Main Building Exhibitors	$182 00
Machinery Building Exhibitors	27 00
Machinery Field Exhibitors	20 00
Premium List Advertisers	228 00
Official Program Advertisers	180 00
Race Program and Score Card Privilege	155 00
Land Show	260 00
Miscellaneous Concessions	25 00
Miscellaneous Exhibitors	100 00
Total	$1,177 00

SCHEDULE "3"—(EXHIBIT "A")

COMPARATIVE STATEMENT OF PLANT ACCOUNTS

1914 and 1915

	Book Value Nov. 30, 1914	Additions Year 1915	Book Value Nov. 30, 1915
Land and Improvements:			
Land	$208,912 50		$208,912 50
Sidewalks	10,466 39		10,466 39
Roads and Drives	10,303 95		10,303 95

Land and improvements—Con.			
Fences	$4,259 63		$4,259 63
Water and Sewer Systems	21,432 18		21,432 18
Race Track	29,730 27		29,730 27
Schedule "3"—(Exhibit "A")	$285,104 92		$285,104 92
Buildings:			
Automobile Building	$37,039 59		$37,039 59
Agricultural Building	15,675 00		15,675 00
Band Stand	2,125 00		2,125 00
Bleachers	1,800 00		1,800 00
Cattle Barns	13,500 00		13,500 00
Dairy Building	14,669 89		14,669 89
Educational Building	5,850 00		5,850 00
Fire Building	1,000 00		1,000 09
Fish Exhibit	....	$147 60	147 60
Grand Stand	57,313 18		57,313 18
Horse Barns	29,936 53		29,936 53
Horticultural Building	15,734 22		15,734 22
Michigan Building	14,446 96		14,446 96
Main Building	29,587 18		29,587 18
Machinery Building	12,774 07		12,774 07
Official Restaurant Building	201 40		201 40
Produce Building	1,800 00		1,800 00
Pay Closets	15,375 00		15,375 00
Poultry Building	3,150 00		3,150 00
Sheep Barns	8,505 00		8,505 00
Swine Barns	9,405 00		9,405 00
Speed Barns	25,896 70		25,896 70
Superintendent's House	278 06		278 06
Schedule "4"—(Exhibit "A")	$316,062 78	$147 60	$316,210 38
Electric Plant and Equipment:			
Electric Signs, etc.			
Schedule "5"—(Exhibit "A")	$19,738 97	$163 95	$19,902 92
Furniture and Fixtures:			
Office—Schedule "6"—(Exhibit "A")	1,011 49	270 00	1,281 49
Sundry Equipment:			
Dairy Building Equipment	$22 68		$22 68
Electrotype	16 00		16 00
Engine and Pumps	1,006 50		1,006 50
Grand Stand Awnings	27 00		27 00
Horse, Harness and Wagons	473 00		473 00
Lawn Seats (Chairs)	135 17	$57 29	192 46
Mattresses, Cots	288 00		288 00
Main Building Booth	00		00
Needle Work Department	30 00		30 00
Night Horse Show Equipment	115 00		115 00
Poultry Department Equipment	1,224 14	17 96	1,242 10
Sundry Tools and Equipment	715 22	369 25	1,084 47
Turnstiles	3,450 73		3,450 73
Schedule "7"—(Exhibit "A")	$7,503 44	$444 50	$7,947 94

SCHEDULE "8"—(EXHIBIT "A")

DEPOSITS ON 1916 CONTRACTS

At November 30, 1915

Louis Gordon	$1,300 00
Arthur St. Armour	50 00
Melvin E. Case	300 00
Goodyear Raincoat Co.	50 00
A. Wegener's Sons	25 00
W. A. Moore & Co.	3,100 00
Total	$4,825 00

SCHEDULE "9"—(EXHIBIT "B")

GENERAL AND ADMINISTRATION EXPENSES

December 1, 1914, to November 30, 1915

Officers Salaries	$5,200 00
Office Salaries	2,547 34
Superintendent's Salary	1,200 00

Fire Insurance	$2,201 16
Accounting	600 00
Auditing	1,200 00
Officers' and Directors' Expenses	815 67
Rent (Office)	750 00
Postage	321 50
Telephone and Telegraph	264 47
Revenue Stamps	30 80
Stationery and Office Supplies	264 44
Commission on Bond Sales	196 62
Legal Expenses	428 00
Drawings and Blue Prints	3 78
Membership (Driving Club)	80 00
Miscellaneous Items	261 11
Total	$16,364 89

SCHEDULE "10"—(EXHIBIT "B")

GENERAL OPERATING EXPENSES

December 1, 1914, to November 30, 1915

General Labor Grounds	$1,044 33
Gatemen Labor	3,333 30
Advance Sale of Tickets	6 71
Police Labor and Expense	1,333 15
Auto Parking	373 00
Timekeeping	137 70
Entry Department	474 39
Watchmen	123 25
Park Maintenance (Labor, etc.)	1,168 27
Walk and Road Repairs	145 71
Water and Sewage System Repairs	37 30
Repairs and Replacements to Electric Equipment	1,409 30
Miscellaneous Repairs	93 95
Tool Expense	5 00
Hospital Expense	83 30
Transportation Department	100 50
Information Bureau	47 50
Concession Expense	102 00
Decorations	275 00
Premiums, Ribbons and Diplomas	330 93
Badges, Buttons, etc.	72 10
Fireworks	1,950 00
Midway Expense	717 50
Toilet Expense	587 85
Gasoline and Lubricants	39 90
Fire Department Expenses	250 04
Horse Feed and Expenses	202 15
Horse Shoeing	15 85
Water, Light and Fuel	1,763 19
Auto Expense	24 00
General Supplies	71 47
Janitors' Supplies	25 31
Disinfecting Cattle Barns	40 00
Miscellaneous Printing	776 15
Miscellaneous Supplies and Expenses (Schedule "14")	715 46
Miscellaneous Building Repairs	781 88
Total	$18,657 44

SCHEDULE "11"—(EXHIBIT "B")

ADVERTISING EXPENSES

December 1, 1914, to November 30, 1915

Publicity Agents' Fees	$1,000 00
Newspaper and Magazine Advertising	8,051 26
Street Car Advertising	432 00
Billboard and Poster Advertising	2,405 20
Photos and Cuts	321 00
Premium List Expense	1,851 15
Official Program Expense	746 74

Miscellaneous Expense:		
Shook's Orchestra	$462 00	
Frank S. Cook	200 00	
W. D. Edenburn	100 00	
Morse Sightseeing Car	100 00	
John P. Church	452 00	
Wm. R. Weinkauf, Distributor of Handbills, etc	157 35	
Campbell, Ewald Co	173 37	
Other Small Items	111 15	
		$1,755 87
Total		$16,563 22

SCHEDULE "12"—(EXHIBIT "B")

SPEED DEPARTMENT EXPENSES

December 1, 1914, to November 30, 1915

Purses	$7,670 00
Grand Stand Labor	1,097 69
Advertising	424 80
Entertainment (Band, etc.)	1,140 00
Sundry Salaries	914 73
Printing and Stationery	393 50
Secretary's Salary	1,065 00
Membership Dues	100 00
Postage	27 00
Suspension Fees	12 00
Miscellaneous Expenses	147 94
Total	$12,992 66

SCHEDULE "13"—(EXHIBIT "B")

SUNDRY DEPARTMENTAL EXPENSES

December 1, 1914, to November 30, 1915

Horse Department:		
Prizes and Premiums	$6,904 20	
Horse Barn Repairs	54 00	
Night Horse Show Expenses	1,168 59	
Entertainment (Band, etc.)	855 00	
Miscellaneous Expenses	426 72	
Total Horse Department Expenses		$9,408 51
Automobile Races:		
Prizes and Premiums	$7,450 50	
Grand Stand Labor	361 09	
Entertainment (Band, etc.)	855 00	
Miscellaneous Expenses	177 50	
Total Automobile Races		8,844 09
Cattle Department:		
Prizes and Premiums	$5,179 20	
Cattle Barn Repairs	53 00	
Judging	177 94	
Miscellaneous Expenses	198 60	
Total Cattle Department Expenses		5,608 74
Sheep Department:		
Prizes and Premiums	$3,204 60	
Sheep Pen (Repairs)	53 00	
Judging	78 65	
Miscellaneous Expenses	167 00	
Total Sheep Department Expenses		3,503 25

Swine Department:		
Prizes and Premiums	$1,912 60	
Judging	96 00	
Miscellaneous Expenses	126 50	
Total Swine Department Expenses		$2,135 10
Fowl Department:		
Prizes and Premiums	$1,726 50	
Judging	84 76	
Miscellaneous Expenses	497 51	
Total Fowl Department Expenses		2,308 77
Farm Products Department:		
Prizes and Premiums	$1,978 25	
Judging	92 36	
Miscellaneous Expenses	114 85	
Total Farm Products Department Expenses		2,185 46
Horticultural Department:		
Prizes and Premiums	$2,291 50	
Judging	97 74	
Miscellaneous Expenses	132 45	
Total Horticultural Department Expenses		2,521 69
Dairy Department:		
Prizes and Premiums	$915 03	
Judging	217 31	
Miscellaneous Expenses	509 66	
Total Dairy Department Expenses		1,642 00
Educational and Physical Education Departments:		
Prizes and Premiums (Educational)	$756 50	
Prizes and Premiums (Physical)	259 35	
Judging	109 50	
Miscellaneous Expenses (Educational)	1,308 45	
Miscellaneous Expenses (Physical)	183 97	
Total Education and Physical Education Department Expenses		2,617 77
Needlework and Fine Arts Departments:		
Prizes and Premiums (Needlework	$222 25	
Miscellaneous Expenses (Needlework)	167 00	
Prizes and Premiums (Fine Arts)	257 00	
Miscellaneous Expenses (Fine Arts)	256 00	
Total Needlework and Fine Arts Department Expenses		902 25
Better Babies' Contest Department:		
Prizes and Premiums	$119 00	
Miscellaneous Expenses	503 45	
Total Better Babies Department Expenses		622 45
Machinery Department:		
Superintendent	$80 00	
Miscellaneous Expenses	78 00	
Total Machinery Department Expenses		158 00
Merchandise and Manufacturing Department:		
Superintendent	$92 90	
Miscellaneous	70 25	
Total Merchandise and Manufacturing Department Expenses		163 15
Miscellaneous Premiums and Prizes:		
Premiums (Trophy Cups)	$817 50	
Athletic Meet	250 00	
Other Premiums	25 00	
Total Miscellaneous Premiums and Prizes		1,092 50
		$43,713 73

NOTE:—The Miscellaneous Expense items include the expenses of watchmen.

SCHEDULE "14"—(SEE SCHEDULE "10")

MISCELLANEOUS SUPPLIES AND EXPENSES

December 1, 1914, to November 30, 1915

Rent for Aladdin House		$248 00
Rent (Chas. Chambers Home)		30 00
Rent Tents, National Tent & Awning Co.		56 70
Rent—J. C. Goss Co., as follows:		
Tent City	$47 75	
Boy Scouts Camp	38 00	
Sheriff's Office (Tent)	38 00	
Superintendent of Transportation (Tent)	11 00	
Boys' Camp (Tents)	85 00	
Expense of Moving Boys' Camp to Boy Scouts' Camp	16 58	
		236 33
Miscellaneous Small Items:		
Labor Change Booth 20	$20 50	
Chas. Denby, for Raincoat lost from his auto at Fair	20 00	
McKinnon Cartage Co., Moving Furniture to and from Fair Grounds	40 00	
Building Inspection	30 00	
Other Small Items	33 93	
		144 43
		$715 46

ELECTION

The Annual Election of the Michigan State Agricultural Society was held in the Administration Building on the State Fair Grounds during the Fair, on Thursday, September 9th, 1915. The Officers to be elected were President and Vice President, and ten members of the Executive Committee. The President appointed as inspectors of the election:

A. G. Griggs, Pontiac,
H. B. Wattles, Troy,
T. F. Marston, Bay City.

They took the oath of office and the polls were opened at ten a. m. and closed at four p. m., in accordance with the By-Laws. The inspectors made a report that the following officers and directors were duly nominated and elected.

Officers.

President—John S. Haggerty.
Vice President—Leonard Freeman.

Directors.

Eugene C. Betz, Monroe.
Frank Coward, Bronson.
H. H. Dow, Midland.
G. W. Dickinson, Pontiac.
C. F. Gates, Sandusky.
Alton T. Roberts, Marquette.
Thomas M. Sattler, Jackson.
John W. Smith, Pt. Huron.
Dudley E. Waters, Grand Rapids.
W. A. Williams, Sandusky.

The total number of votes cast were sixty-four, all of which were cast in favor of the candidates named.

The President announced the result of the ballot and declared the persons above named duly elected. The term of office beginning the first Tuesday in December, 1915. The officers were elected for one year and directors for two years.

G. W. DICKINSON,
Secretary-Manager.

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